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ABSTRACT

This document contains the materials for a competency-based course in diesel technology and electrical and electronic systems that is tied to measurable and observable learning outcomes identified and validated by an advisory committee of business and industry representatives and teachers. The competencies addressed align with the medium/heavy truck program standards developed by the National Automotive Technician's Education Foundation in conjunction with the National Institute for Automotive Service Excellence. This complete teacher edition consists of the following items: (1) introductory pages (list of tools and equipment; basic skills matrix; basic skills icons and classifications; instructional/task analysis; national skills crosswalk; training and competency profile; guidelines for using the publication); (2) teacher pages (transparency masters; teacher supplements; learning activities sheets; answers to written tests; answers to assignment sheets; suggested activities; and unit contents); and (3) the student edition. The student edition contains objective sheets, information sheets, student supplements, assignment sheets, and job sheets for 11 units of study on topics such as the following: (1) diesel electrical and electronic systems; (2) circuits and circuit devices; (3) basic diagnostic and repair skills; (4) vehicle computer controls; (5) battery diagnosis and servicing;

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(6) starting and charging systems; (7) miscellaneous electrical accessories; (8) lighting systems; and (9) driver information systems. (MN)

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ED 457 403

Diesel Technology:
Electrical and Electronic Systems.
Teacher Edition [and] Student Edition.

Allan Ready, Ricky Kauffman, Jerry Bogle

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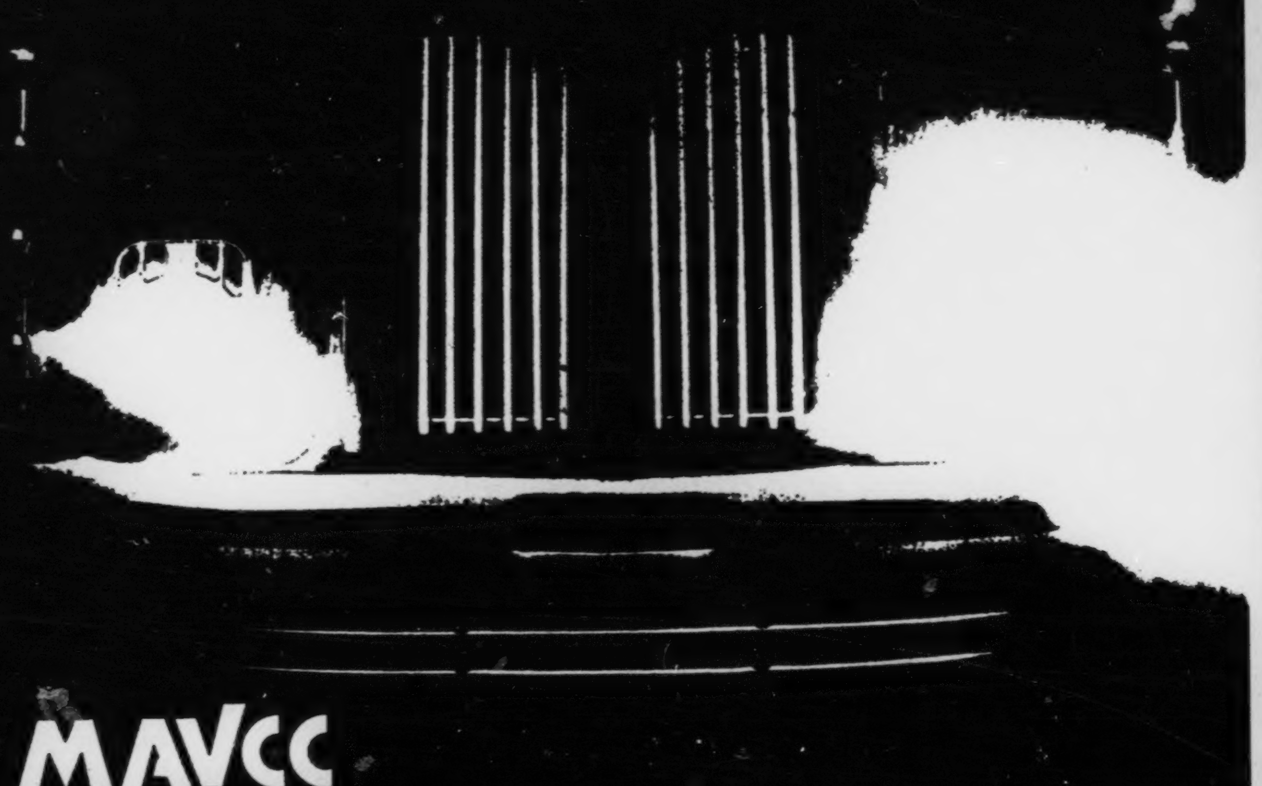

MAVCC

Teacher Edition

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Diesel Technology: Electrical and Electronic Systems

Teacher Edition

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Units of Instruction

Unit 1: Introduction to Diesel Electrical and Electronic Systems
Unit 2: Understanding Circuit and Circuit Devices
Unit 3: Developing Basic Diagnosis and Repair Skills
Unit 4: Understanding Vehicle Computer Controls
Unit 5: Battery Diagnosis and Servicing
Unit 6: Starting Systems Diagnosis and Repair
Unit 7: Charging Systems Diagnosis and Repair
Unit 8: Lighting Systems Diagnosis and Repair
Unit 9: Driver Information Systems Diagnosis and Repair
Unit 10: Related Electrical Components
Unit 11: Miscellaneous Electrical Accessories

Foreword

When MAVCC began the process for revising its diesel mechanics series, we wanted to develop instructional materials that would provide students with the cognitive (knowing), psychomotor (doing), and affective (attitude) skills necessary to be successful in the diesel trade and that would address the emerging technology in the field. With the help of extremely qualified teachers, industry representatives, and writers, our diesel technology series offers secondary and postsecondary students an excellent opportunity for learning required skills in the diesel industry.

The series aligns with the medium/heavy duty truck task list developed by the National Automotive Technicians Education Foundation (NATEF) and used by the National Institute for Automotive Service Excellence (ASE) in the certification of medium/heavy duty truck technicians. Our series will address all but one of the ASE certification skills, gasoline engines, and will include the following publications: *Introduction, Safety Skills, Workplace Skills, Brakes, Steering and Suspension, Engines, Electrical and Electronic Systems, Air Conditioning, Drive Trains, Hydraulics*, and *Preventive Maintenance*. Each publication will include a matrix showing where the NATEF tasks are being taught.

The instructional materials are designed for student use and to assist teachers in organizing and improving instruction. Their design is based on the curriculum alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching to those objectives (information, assignment, and job sheets), and assessing to those same objectives (criterion-referenced evaluation instruments).

As with all MAVCC publications, teachers are encouraged to localize and personalize these materials to meet the needs of individual students, the community, and prospective employers. Teachers are also encouraged to develop strategies for motivating their students.

Special attention should be given to the basic skills matrix in the introductory pages and to the teaching suggestions in each unit of instruction. These suggestions present academic skills being reinforced by the instructional materials and ways to increase reinforcement of workplace skills. By reinforcing basic skills, the teacher will assist students in becoming more productive workers.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please call or write us.

Mervin Birdwell, Chair
MAVCC Board of Directors

Jane Huston
MAVCC Executive Director

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The contents of this publication were initially planned and reviewed by the following committee members:

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Thanks are also extended to Glenn Fleming, Project Coordinator, and to Jane Huston, MAVCC Executive Director.

Use of This Publication

Diesel Technology: Electrical and Electronic Systems is available in both a teacher and student edition. The contents of these materials are tied to measurable and observable learning outcomes that were identified and validated by the Electrical and Electronic Systems advisory committee, comprised of business/industry representatives and teachers. Competencies align with the Medium/Heavy Truck Program Standards developed by the National Automotive Technician's Education Foundation (NATEF) in conjunction with the National Institute for Automotive Service Excellence (ASE).

Teacher Edition

The complete teacher edition consists of introductory pages, teacher pages, and the student edition. Materials are loose-leaf and three-hole punched and are divided into units of instruction that may be broken into more than one lesson or class period. For added flexibility, each unit is individually numbered beginning with a T for teacher page, followed by the unit number and page number.

Example:

Page 17 of Unit 3 in the teacher pages is represented as T 3–17.

MAVCC—*Diesel Technology: Electrical and Electronic Systems* T 3–17

Page 1 of Unit 5 in the teacher pages is represented as T 5–1.

MAVCC—*Diesel Technology: Electrical and Electronic Systems* T 5–1

Pages in the student edition are numbered beginning with the unit number, followed by the page number.

Example:

Page 7 of Unit 5 in the student edition is represented as Page 5–7.

MAVCC *Diesel Technology: Electrical and Electronic Systems* **Page 5—7**

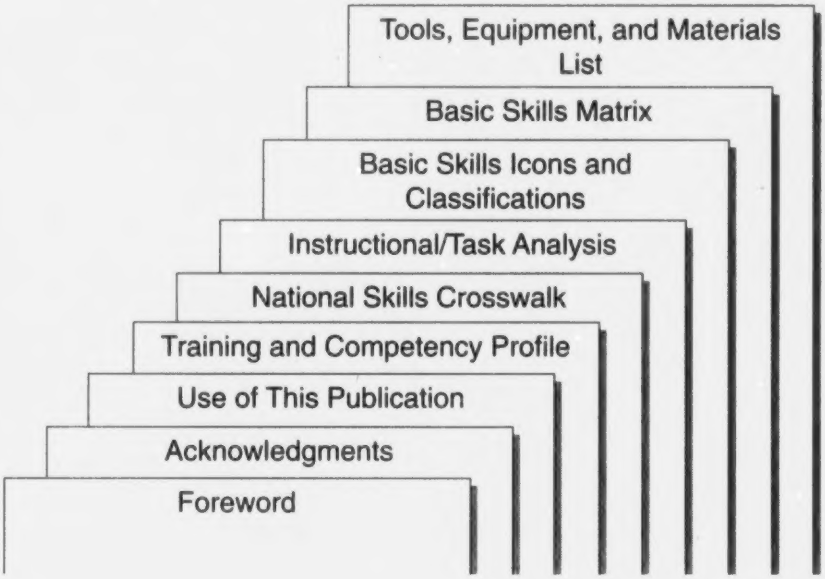
Use of This Publication

For group instruction, the teacher should determine the best way to teach each objective and allow for student participation. For self-paced or individualized instruction, students should be provided with opportunities to become involved in planning and being responsible for their own education. Careful study of each unit of instruction by the teacher will help to determine the following:

- amount of material that can be covered in each class period;
- supplies and materials required for assignment sheets and job sheets;
- resource people who must be contacted;
- supplementary materials to be ordered;
- skills that must be demonstrated and the amount of class time needed for demonstrations; and
- amount of class time needed for student practice and return demonstrations of mastered skills.

Teachers are encouraged to localize and personalize these materials to meet the needs of individual students, the community, and prospective employers.

Introductory Pages

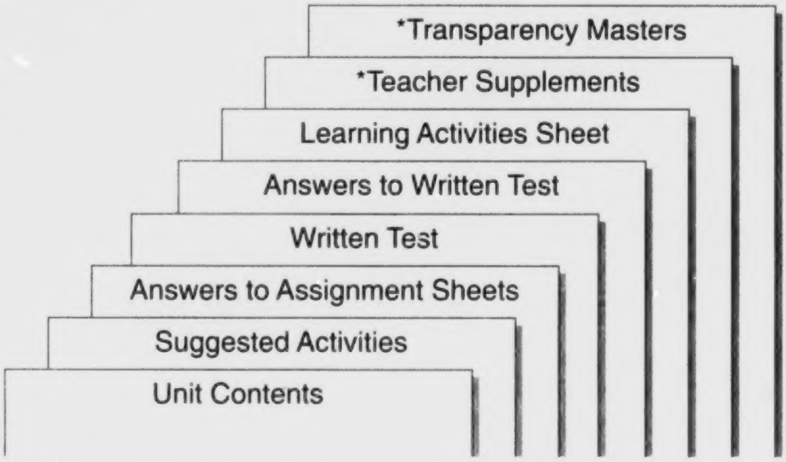

Tools, Equipment, and Materials List
Basic Skills Matrix
Basic Skills Icons and Classifications
Instructional/Task Analysis
National Skills Crosswalk
Training and Competency Profile
Use of This Publication
Acknowledgments
Foreword

In addition to general information, such as the table of contents, acknowledgments, and the use of this publication, the following tools have been provided to assist administrators and teachers in planning for instruction.

- ☐ **Training and Competency Profile.** This form may be copied and used to record information about each student, such as enrollment dates, class attendance, and work experience, and to document the student's mastery of specific job competencies. It can also be used to provide information about the student's qualifications to potential employers and/or for entry into advanced training programs.
- ☐ **National Skills Duty/Task Crosswalk.** This document identifies the national skill standards covered in this publication and lists specifically where these skills are located by unit number and objective.
- ☐ **Instructional/Task Analysis.** This document provides a quick review of the contents of this publication by identifying the cognitive skills (what the student should know) and psychomotor skills (what the student should be able to do) addressed in each unit of instruction.
- ☐ **Basic Skills Icons and Classifications**. This page provides a reference guide of the graphic symbols that are used to identify the basic academic and workplace skills included in each focus assignment, assignment sheet, and job sheet.
- ☐ **Basic Skills Matrix.** This document graphically summarizes the academic and workplace skills training included in the instructional materials, unit by unit. It should be helpful to teachers in planning for instruction, and to administrators as documentation that basic skills are being taught as part of the vocational training.
- ☐ **Tools, Equipment, and Materials List.** This document provides a comprehensive list of those items needed in a vocational program for students to complete training. It also can assist administrators and teachers in determining program costs.

Use of This Publication

Teacher Pages


*Transparency Masters
*Teacher Supplements
Learning Activities Sheet
Answers to Written Test
Written Test
Answers to Assignment Sheets
Suggested Activities
Unit Contents

*Designates components that may not appear in every unit of instruction

Teachers should study the teacher and student pages before introducing the unit, allowing enough time to obtain supplemental materials and to contact outside resource persons.

☐ **Suggested Activities.** This component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, a list of references used in the development of each unit, and a list of suggested supplemental resources (books, posters, pamphlets, videotapes, computer software, and Internet sites) that may be used to enhance instruction.

Instructions for evaluating student performance on the assignment sheets and job sheets are also included in the suggested activities section. Teachers should select and discuss with students the rating scale that will be used.

☐ **Answers to Assignment Sheets.** An answer key is provided, when applicable, to assist the teacher in evaluating student performance on a given assignment.

☐ **Written Test.** This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction, and serves as both a pretest and posttest to assist teachers in measuring each student's competency gains. (Assignment sheet and job sheet objectives are not evaluated on the written test.) If the teacher has added, deleted, or modified any objectives, appropriate changes should be made to both the test and answers to the written test.

Tests may be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for a final test at the end of each term if desired. The written test is included in the teacher edition only and should be duplicated for student use.

☐ **Answers to Written Test.** An answer key is provided to assist the teacher in evaluating student performance on the written test.

☐ **Learning Activities Sheet.** This component provides a model for teachers to use in implementing a self-paced or individualized program, and guides the student through the required components in the student edition (objective sheet, information sheet, student supplements, assignment sheets, and job sheets). The teacher should modify the learning steps as needed to incorporate resources available in the classroom (videotapes, computer software, magazines, etc.) and to address instructional strategies that may be needed to enhance learning for each student. Final copies should be distributed for student use.

The following icons will be used on the learning activities sheet to denote steps that require additional resources:

📖 Read a book, magazine, or journal article

💻 Use a CBT program or other software application

WWW Access a site on the World Wide Web

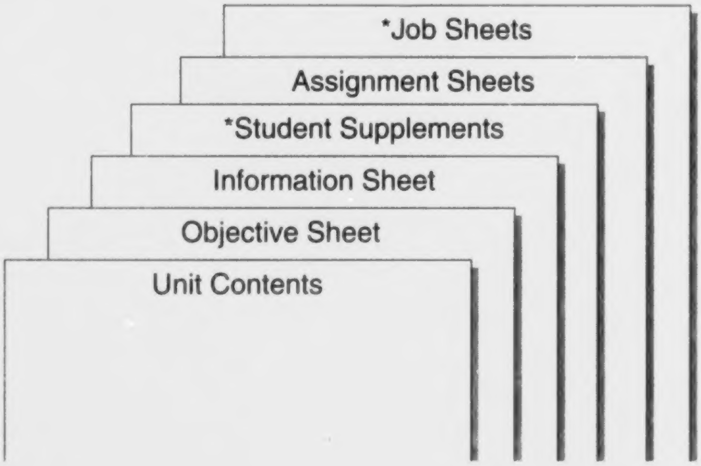
🖥 Look at PowerPoint® or other computer presentation

📼 Watch a videotape

☐ **Teacher Supplements.** These are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student; with remedial information or practice to assist the less-advanced student; and with state-of-the-art information in which the teacher may not have a background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

- ☐ **Transparency Masters.** These overheads are used to direct the students' attention to the topic of classroom discussion. Transparencies allow the student to see as well as hear the information being presented, thus reinforcing the learning process. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction. Some of these items may also appear with the appropriate objectives in the information sheet in the student edition. The teacher may make acetate copies from the masters or, in most cases, complete transparency sets are available for purchase.

Student Edition



*Designates components that may not appear in every unit of instruction

For best results, students should be provided with a copy of the student edition and should be allowed to take notes in the margins as additional information is provided by the instructor or as the student acquires additional information through library or Internet research.

- ☐ **Objective Sheet.** This component summarizes each unit for the student and teacher. The objective sheet is based on established performance objectives that state the goals for successful completion of a unit of instruction. Objectives are stated in two forms: unit objectives that state the expected performance of each student after completion of the unit and specific (enabling) objectives that state what the student must be able to do to reach the unit objective.

  The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods.

Teachers should modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion-referenced test items to cover the new objectives.

☐ **Information Sheet.** This component provides the student with the essential information for meeting the cognitive objectives in the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in the margins for students and teachers to add notes that clarify and/or expand upon the information presented.

☐ **Student Supplements.** This component is included in a unit of instruction when additional information is needed in order for students to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment and/or job sheets.

☐ **Assignment Sheets.** The assignment sheets address the learning levels at or above the application level of Bloom's taxonomy. They provide students with an opportunity to use higher-order thinking skills, such as problem solving, synthesizing, analyzing, and evaluating. In addition, they may provide additional opportunities for students to develop their language skills.

Assignment sheets can be paper-and-pencil activities, as well as those using computer software, videotapes, models, handouts, or other resources as appropriate. Criteria are provided to evaluate student performance objectively.

☐ **Job Sheets.** Job sheets are designed as skill tests and give the instructor direction as to the psychomotor skills to be taught, and provide the criteria to evaluate student performance objectively. They also help provide potential employers with a picture of the skills being taught during training and the performances that might be reasonably expected from an individual who has completed the training.

The teacher should provide students with a copy of each job sheet and/or the procedure's manual and/or job specifications when necessary. The teacher should also discuss the equipment and materials that will be needed for the job and the criteria that will be used to evaluate the student's performance, and demonstrate the procedure prior to having students practice the procedure. Safety should be stressed as part of each demonstration.

When a student is ready to be evaluated, the teacher should follow the instructions for evaluating student performance which may be found in the suggested activities component of the teacher unit.

As you use these instructional materials we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please write us at 1500 West Seventh Avenue, Stillwater, OK 74074-4364, or E-mail us at mavcc@okvcareertech.org.

Training and Competency Profile

Student Information

Program ____________________ Instructor ____________________

Name ____________________ Soc. Sec. No. ____________________

Address ____________________ Phone ____________________

Grade ____________ School ____________________

Allergies/Disabilities that might require special accommodation for training (please specify)

____

In case of emergency, contact ____________________ Phone ____________________

Record of Enrollment

Date of Enrollment ____-____-____ Total Class Hours ________ Total Hours Absent ________

Date of Withdrawal ____-____-____ Total On-the-Job Training Hours ________ Total Hours Tardy ________

Date of Completion ____-____-____ Total Lab Hours ________

On-the-Job Training/Work Experience

____________________ ____________________
Place of Employment Address

____________________ ____________________
Supervisor's Name Phone

____________________ ____________________
Duration of Employment Job Title

____
Job Responsibilities

____________________ ____________________
Place of Employment Address

____________________ ____________________
Supervisor's Name Phone

____________________ ____________________
Duration of Employment Job Title

____
Job Responsibilities

Training and Competency Profile

Student Evaluation

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focuses on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Rating Scale: Option A

4	Skilled—Can perform job with no additional training
3	Moderately Skilled—Has performed job during training program; limited additional training may be required.
2	Limited Skill—Has performed job during training program; additional training is required to develop skill.
1	Unskilled—Is familiar with process, but is unable to perform job.
0	No Exposure—No information or practice provided during training program, complete training required.
NA	Non-applicable.

Rating Scale: Option B

Yes—Can perform with no additional training
No—Is unable to perform satisfactorily

Unit 1: Introduction of Diesel Electrical and Electronic Systems

_______ 1. Calculate current using Ohm's law
_______ 2. Calculate voltage using Ohm's law
_______ 3. Calculate resistance using Ohm's law
_______ 4. Predict changes in voltage, current, and resistance in a circuit
_______ 5. ______________________________
_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 2: Understanding Circuits and Circuit Devices

_______ 1. Explain what the color bands found on resistors represent, and use the color bands on a resistor to determine its resistance value
_______ 2. Determine correct replacement fuses
_______ 3. Use wire color and circuit identification codes to locate circuit information
_______ 4. Use wiring diagrams to locate information about circuits
_______ 5. Use your knowledge of electric/electronic theory and circuit devices to predict changes in current, voltage, and resistance in a series circuit
_______ 6. Inspect, test, and replace spike suppresion diodes/reistors
_______ 7. ______________________________
_______ Written test scores
Pretest score ________%
Posttest score ________%

Unit 3: Developing Basic Diagnosis and Repair Skills

_______ 1. Identify types of circuits and circuit devices on a circuit
_______ 2. Perform calculations using units of electrical measurement
_______ 3. Prepare to measure current, voltage, resistance, and frequency with a multimeter
_______ 4. Calculate resistance in sample circuits
_______ 5. Calculate current in sample circuits
_______ 6. Calculate voltage drops in sample circuits
_______ 7. Calculate voltage in sample circuits
_______ 8. Calibrate and make functionality tests on electrical diagnostic instruments
_______ 9. Check electrical/electronic circuits with jumper wires
_______ 10. Check electrical circuits with a test light
_______ 11. Check voltage in electrical/electronic circuits with a multimeter
_______ 12. Check voltage drops in electrical/electronic circuits with a multimeter
_______ 13. Check current flow in electrical/electronic circuits with a multimeter
_______ 14. Check continuity and resistance in electrical/electronic circuits and components with a multimeter
_______ 15. Find shorts, grounds, opens, and high resistance problems in electrical/electronic circuits
_______ 16. Tin a soldering iron or gun
_______ 17. Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits
_______ 18. Inspect, test, and replace fusible links, circuit breakers, and fuses
_______ 19. ______________________________
_______ Written test scores
Pretest score ________%
Posttest score ________%

Training and Competency Profile

Unit 4: Understanding Vehicle Computer Controls

_______ 1. Demonstrate how a potentiometer functions as a sensor

_______ 2. Interpret SAE fault code identifiers

_______ 3. Use a DVOM to measure reference voltage output from the electronic control module

_______ 4. Access vehicle fault codes using the vehicle's computerized diagnostic system; determine needed repairs

_______ 5. ______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 5: Battery Diagnosis and Servicing

_______ 1. Evaluate factors in selecting the appropriate battery for a vehicle

_______ 2. Maintain and restore electronic memory functions

_______ 3. Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold-downs

_______ 4. Make a battery state-of-charge test

_______ 5. Make a battery capacity (load) test

_______ 6. Determine battery state-of-charge using an open circuit voltage test

_______ 7. Slow and fast charge a battery

_______ 8. Diagnose parasitic (key-off) battery drain problems

_______ 9. Connect batteries in series, parallel, and series-parallel

_______ 10. Jump-start a vehicle

_______ 11. ______________________________

_______ Written Test scores
Pretest score ________%
Posttest score ________%

Unit 6: Starting Systems Diagnosis and Repair

_______ 1. Diagnose starting system problems

_______ 2. Make a no-load starter current draw test

_______ 3. Make starter circuit voltage drop tests

_______ 4. Inspect, test, and repair or replace switches, connectors, and wires of starter control circuits

_______ 5. Inspect, test, and replace starter relays and solenoids

_______ 6. Remove and replace starter

_______ 7. ______________________________

_______ Written test scores
Pretest score ________%
Posttest score ________%

Unit 7: Charging Systems Diagnosis and Repair

_______ 1. Diagnose charging system problems that cause an undercharge, a no-charge, or an overcharge condition

_______ 2. Inspect, adjust, and replace alternator drive belts, pulleys, and tensioners.

_______ 3. Make a charging system output test; determine needed repairs

_______ 4. Make a charging circuit voltage drop test; determine needed repairs

_______ 5. Test an S.I. series alternator

_______ 6. Inspect, repair, or replace connectors and wires of charging circuits

_______ 7. Remove, inspect, and replace an alternator

_______ 8. ______________________________

_______ Written test scores
Pretest score ________%
Posttest score ________%

Unit 8: Lighting Systems Diagnosis and Repair

_______ 1. Diagnose the cause of headlights and daytime running lights problems

_______ 2. Diagnose the cause of parking lights, clearance lights, and taillights problems

_______ 3. Diagnose the cause of stoplight (brake light) problems

_______ 4. Diagnose the cause of turn signals and hazard lights problems

_______ 5. Diagnose the cause of back-up lights problems

_______ 6. Diagnose the cause of instrument lighting problems

_______ 7. Diagnose the cause of courtesy lights problems

_______ 8. Inspect, replace, and aim headlights/bulbs

_______ 9. Inspect, test, and replace light bulbs and test sockets

_______ 10. Inspect, test, repair and replace the components of a headlights and daytime running lights circuit

_______ 11. Inspect, test, repair and replace the components of a parking light, clearance Light and taillight circuit

_______ 12. Inspect, test, repair and replace the components of a stoplight (brake light) circuit

_______ 13. Inspect, test, repair and replace the components of a turn signal and hazard lights circuit

_______ 14. Inspect, test, repair and replace the components of a back-up lights circuit

_______ 15. Inspect, test, repair and replace the components of an instrument lighting circuit

_______ 16. Inspect, test, repair and replace the components of a courtesy lights circuit

_______ 17. Inspect, test, repair and replace the components of tractor-to-trailer lights circuit

_______ 18. ______________________________

_______ Written test scores
Pretest score ________%
Posttest score ________%

Training and Competency Profile

Unit 9: Driver Information Systems Diagnosis and Repair

_______ 1. Diagnose the cause(s) of faulty gauge readings

_______ 2. Diagnose the cause(s) of the faulty operation of an electronic instrument cluster, warning light, indicator light, and driver information circuit

_______ 3. Diagnose the cause(s) of the faulty operation of audible warning devices

_______ 4. Inspect, test, repair, and replace the components of a gauge circuit

_______ 5. Inspect, test, repair, and replace the components of an electronic instrument cluster, warning light, indicator light, and driver information circuit

_______ 6. Inspect, test, repair, and replace components of audible warning device circuits

_______ 7. Inspect, test, replace, and calibrate electronic speedometer, odometer, and tachometer circuits

_______ 8. ______________________________

_______ Written test scores
Pretest score _______%
Posttest score _______%

Unit 10: Related Electrical Components

_______ 1. Diagnose the cause of horn problems

_______ 2. Diagnose the cause of wiper problems

_______ 3. Diagnose the cause of windshield washer problems

_______ 4. Diagnose the cause of heater problems

_______ 5. Diagnose the cause of air conditioning problems

_______ 6. Inspect, test, repair, and replace the components of a horn circuit

_______ 7. Inspect, test, repair, and replace the components of wiper circuits

_______ 8. Inspect, test, repair, and replace intermittent (pulsing) wiper controls

_______ 9. Inspect, test, repair, and replace the components of a windshield washer circuit

_______ 10. Inspect, test, repair, and replace the components of a heater circuit

_______ 11. Inspect, test, repair, and replace the components of an air conditioning circuit

_______ 12. Inspect, test, repair, and replace the components of an engine block heater

_______ 13. ______________________________

_______ Written test scores
Pretest score _______%
Posttest score _______%

Unit 11: Miscellaneous Electrical Accessories

_______ 1. Diagnose the cause of power window problems

_______ 2. Diagnose the cause of heated, lighted, and electrically operated mirror problems

_______ 3. Diagnose the cause of electric door lock problems

_______ 4. Diagnose the cause of radio reception problems

_______ 5. Diagnose the cause(s) of the airbag warning light staying on or flashing

_______ 6. Inspect, test, repair, and replace the parts of a power window

_______ 7. Inspect, test, repair, and replace the parts of a heated, lighted, and electrically operated mirror

_______ 8. Inspect, test, repair, and replace the parts of an electric door lock

_______ 9. Inspect, test, repair, and replace the parts of anti-theft systems

_______ 10. Inspect, test, repair, and replace the parts of a sound system

_______ 11. Remove and reinstall audio system components (unit)

_______ 12. Inspect, test, repair, and replace the parts of an airbag system

_______ 13. Inspect, test, repair, and replace the parts of a cigar lighter/auxiliary power outlet

_______ 14. Inspect, test, repair, and replace the parts of a clock

_______ 15. ______________________________

_______ Written test scores
Pretest score _______%
Posttest score _______%

NATEF Crosswalk

The following NATEF Electrical/Electronic Systems tasks (rev. 2001) are covered in this publication. The chart shows where each task is located within the publication. The first column identifies the NATEF task by name and number. The second column identifies the exact location by unit number and assignment sheet or job sheet number.

NATEF Tasks	MAVCC Tasks
VI. Electrical/Electronic Systems	
A. General Electrical Systems Diagnosis	
1. Read, interpret and diagnose electrical/ electronic circuits using wiring diagrams.	Unit 2, Assignment Sheet 4 — Using wiring diagrams to locate information about circuits. Unit 3, Assignment Sheet 1 — Identify types of circuits and circuit devices on a circuit.
2. Check continuity in electrical/electronic circuits using appropriate test equipment.	Unit 3, Job Sheet 1 — Calibrate and make functionality tests on electrical diagnostic instruments. Unit 3, Job Sheet 2 — Check electrical/electronic circuits with jumper wires. Unit 3, Job Sheet 3 — Check electrical circuits with a test light. Unit 3, Job Sheet 7 — Check continuity and resistance in electrical/electronic circuits and components with a multimeter.
3. Check applied voltages, circuit voltages, and voltage drops in electrical/electronic circuits using a digital multimeter (DMM).	Unit 3, Assignment Sheet 3 — Prepare to measure current, voltage, resistance, and frequency with a multimeter. Unit 3, Job Sheet 1 — Calibrate and make functionality tests on electrical diagnostic instruments. Unit 3, Job Sheet 4 — Check voltage in electrical/electronic circuits with a multimeter. Unit 3, Job Sheet 5 — Check voltage drops in electrical/electronic circuits with a multimeter.
4. Check current flow in electrical/electronic circuits and components using a digital multimeter (DMM) or clamp-on ammeter.	Unit 3, Assignment Sheet 3 — Prepare to measure current, voltage, resistance, and frequency with a multimeter. Unit 3, Job Sheet 1 — Calibrate and make functionality tests on electrical diagnostic instruments. Unit 3, Job Sheet 6 — Check current flow in electrical/electronic circuits and components with a multimeter.

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
5. Check resistance in electrical/electronic circuits and components using a digital multimeter (DMM) or clamp-on ammeter.	Unit 3, Assignment Sheet 3 — Prepare to measure current, voltage, resistance, and frequency with a multimeter. Unit 3, Job Sheet 1 — Calibrate and make functionality tests on electrical diagnostic instruments. Unit 3, Job Sheet 7 — Check continuity and resistance in electrical/electronic circuits and components with a multimeter.
6. Find shorts, grounds, and opens in electrical/electronic circuits.	Unit 3, Job Sheet 8 — Find shorts, grounds, opens, and high resistance problems in electrical/electronic circuits.
7. Diagnose parasitic (key-off) battery drain problems.	Unit 5, Job Sheet 7 — Diagnose parasitic (key-off) battery drain problems.
8. Inspect and test fusible links, circuit breakers, relays, solenoids, and fuses; replace as needed.	Unit 2, Assignment Sheet 2 — Determine correct replacement fuses. Unit 3, Job Sheet 11 — Inspect, test, and replace fusible links, circuit breakers, and fuses.
9. Inspect and test spike suppression diodes/resistors; replace as needed.	Unit 2, Job Sheet 1 — Inspect, test, and replace spike suppression diodes/resistors.
B. Battery Diagnosis and Repair	
1. Perform battery load test; determine needed action.	Unit 5, Job Sheet 4 — Make a battery capacity (load) test.
2. Determine battery state-of-charge using an open circuit voltage test.	Unit 5, Job Sheet 3 — Make a battery state-of-charge test. Unit 5, Job Sheet 5 — Determine battery state-of-charge using an open circuit voltage test.
3. Inspect, clean, and service battery; replace as needed.	Unit 5, Job Sheet 2 — Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold downs.
4. Inspect and clean battery boxes, mounts, and hold downs; repair or replace as needed.	Unit 5, Job Sheet 2 — Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold downs.
5. Charge battery using slow or fast charge method as appropriate.	Unit 5, Job Sheet 6 — Show and fast charge a battery.
6. Inspect, test, and clean battery cables and connectors; repair or replace as needed.	Unit 5, Job Sheet 2 — Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold downs.
7. Jump start a vehicle using jumper cables and a booster battery or auxiliary power supply using proper safety procedures.	Unit 5, Job Sheet 9 — Jump start a vehicle.

NATEF Tasks	MAVCC Tasks
C. Starting System Diagnosis and Repair	
1. Perform starter current draw test; determine needed action.	Unit 6, Job Sheet 1 — Make a no-load starter current draw test (off vehicle).
2. Perform starter circuit cranking voltage and votage drop tests; determine needed action.	Unit 6, Job Sheet 2 — Make starter circuit voltage drop tests.
3. Inspect, test, and replace components (key switch, push button, and/or magnetic switch) and wires in the starter control circuit.	Unit 6, Job Sheet 3 — Inspect, test, and repair or replace switches, connectors and wires of start control circuits.
4. Inspect, test, and replace starter relays and solenoids/switches.	Unit 6, Job Sheet 4 — Inspect, test, and replace starter relays and solenoids.
5. Remove and replace starter; inspect flywheel ring gear or flex plate.	Unit 6, Job Sheet 5 — Remove and replace a starter.
D. Charging System Diagnosis and Repair	
1. Diagnose instrument panel mounted volt meters and/or indicator lamps that show a no charge, low charge, or overcharge condition; determine needed action.	Unit 9, Assignment Sheet 1 — Diagnose the cause(s) of faulty gauge readings.
2. Diagnose the cause of a no charge, low charge, or overcharge condition; determine needed action.	Unit 7, Assignment Sheet 1 — Diagnose charging system problems that cause an undercharge, a no-charge, or an overcharge condition.
3. Inspect, adjust, and replace alternator drive belts, pulleys, fans, tensioners, and mounting brackets.	Unit 7, Job Sheet 1 — Inspect, adjust, and replace alternator drive belts, pulleys, and tensioners.
4. Perform charging system voltage and amperage output test; determine needed action.	Unit 7, Job Sheet 2 — Make a charging system output test; determine needed repairs.
5. Perform charging circuit voltage drop tests; determine needed action.	Unit 7, Job Sheet 3 Make a charging system voltage drop test; determine needed repairs.
6. Remove and replace alternator.	Unit 7, Job Sheet 6 — Remove, inspect, and replace an alternator.
7. Inspect, repair, or replace connectors and and wires in the charging styem.	Unit 7, Job Sheet 5 — Inspect, repair or replace connectors and wires of charging circuits.
8. Diagnose AC voltage teakage (failed rectifier) at alternator output; determine needed action.	Unit 7, Job Sheet 2 — Make a charging system output test; determine needed repairs.

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
E. Lighting Systems Diagnosis and Repair	
1. Headlights, Daytime Running Lights, Parking, Clearance, Tail, Cab, and Instrument Panel Lights	
1. Diagnose the cause of brighter than normal, intermittent, dim, or no headlight and daytime running light (DRL) operation.	Unit 8, Assignment Sheet 1 — Diagnose the cause of headlights and daytime running lights problems.
2. Test, aim, and replace headlights.	Unit 8, Job Sheet 1 — Inspect, replace, and aim headlights/bulbs.
3. Test headlight and dimmer circuit switches, relays, wires, terminals, connectors, sockets, and control components; repair or replace as needed.	Unit 8, Job Sheet 2 — Inspect, test, and replace light bulbs and test sockets. Unit 8, Job Sheet 3 — Inspect, test, and replace the components of a headlights and daytime running lights circuit.
4. Inspect and test switches, bulbs/LEDs, sockets, connectors, terminals, relays, and wires of parking, clearance, and taillight circuits; repair or replace as needed.	Unit 8, Assignment Sheet 2 — Diagnose the cause of parking lights, clearance lights, and taillights problems. Unit 8, Job Sheet 4 — Inspect, test, repair, and replace the components of a parking light, clearance light, and taillight circuit.
5. Inspect and test instrument panel light circuit switches, relays, bulbs, sockets, connectors, terminals, wires, and printed circuit/control modules; repair or replace as needed.	Unit 8, Assignment Sheet 6 — Diagnose the cause of instrument lighting problems. Unit 8, Job Sheet 8 — Inspect, test, repair, and replace the components of an instrument lighting circuit.
6. Inspect and test interor cab light circuit switches, bulbs, sockets, connectors, terminals, and wires; repair or replace as needed.	Unit 8, Assignment Sheet 7 — Diagnose the cause of courtesy lights problems. Unit 8, Job Sheet 9 — Inspect, test, repair, and replace the components of a courtesy lights circuit.
7. Inspect and test tractor-to trailer multi-wire connector(s); repair or replace as needed.	Unit 8, Job Sheet 10 — Inspect, test, repair, and replace the components of tractor-to-trailer lights circuit.
2. Stoplights, Turn Signals, Hazard Lamps, and Back-up Lights	
1. Inspect, test, and adjust stoplight circuit switches; bulbs/LEDs, sockets, connectors, terminals, and wires; repair or replace as needed.	Unit 8, Assignment Sheet 1 — Diagnose the cause of stoplight (brake light) problems. Unit 8, Job Sheet 5 — Inspect, test, adjust, repair, and replace the components of a stoplight (brake light) circuit.
2. Inspect and test turn signal and hazard circuit flasher(s), switches, relays, bulbs/LEDs, sockets, connectors, terminals, and wires; repair or replace as needed.	Unit 8, Assignment Sheet 4 — Diagnose the cause of turn signals and hazard lights problems. Unit 8, Job Sheet 6 — Inspect, test, repair, and replace the components of a turn sign and hazard lights circuit.

NATEF Tasks	MAVCC Tasks
3. Inspect, test, and adjust back-up lights and warning device circuit switches, bulbs/LEDs, sockets, horns, buzzers, connectors, terminals, and wires; repair or replace as needed.	Unit 8, Assignment Sheet 5 — Diagnose the cause of back-up lights problems. Unit 9, Assignment Sheet 3 — Diagnose the cause(s) of the faulty operation of audible warning devcies. Unit 8, Job Sheet 7 — Inspect, test, repair, and replace the components of a back-up lights circuit. Unit 9, Job Sheet 3 — Inspect, test, repair, and replace components of audible warning device circuits.
F. Gauges and Warning Devices Diagnosis and repair	
1. Interface with vehicle's on-board computer; perform diagnostic procedure using recommended electronic diagnostic equipment and tools (to include PC base software, and/or data scan tools); determine needed action.	Unit 4, Assignment Sheet 2 — Interpret SAE fault codes. Unit 4 Job Sheet 2 — Access vehicle fault codes using the vehicle's computerized diagnostic system; determine needed repairs.
2. Diagnose the cause of intermittent, high, low, or no gauge readings; determine needed action.	Unit 9, Assignment Sheet 1 — Diagnose the cause(s) of faulty gauge readings.
3. Diagnose the cause of data bus-driven gauge malfunctions; determine needed action.	Unit 9, Assignment Sheet 1 — Diagnose the cause(s) of faulty gauge readings. Unit 9, Job Sheet 2 — Inspect, test, repair, and replace the components of an electronic instrument cluster, warning light, indicator light, and driver information circuit.
4. Inspect and test gauge circuit sending units, gauges, connectors, terminals, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 9, Job Sheet 1 — Inspect, test, repair, and replace the components of a gauge circuit.
5. Inspect and test warning devices (lights and audible) circuit sending units, bulbs/LEDs, sockets, connectors, wires, and printed circuits/control modules; repair or replace as needed.	Unit 4, Job Sheet 1 — Use a DVOM to measure reference voltage output from the electronic control module. Unit 9, Job Sheet 3 — Inspect, test, repair, and replace components of audible warning device circuits.
6. Inspect, test, replace, and calibrate (if applicable) electronic speedometer, odometer, and tachometer systems.	Unit 9, Assignment Sheet 2 — Diagnose the cause(s) of the faulty operation of an electronic instrument cluster, warning light, indicator light, and driver information light.
G. Related Electrical Components	
1. Diagnose the cause of constant, intermittent, or no horn operation; determine needed action.	Unit 10, Assignment Sheet 1 — Diagnose the cause of horn problems.

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
2. Inspect and test horn circuit relays, horns, switches, connectors, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals and wires of electrical/electronic circuits. Unit 10, Job Sheet 1 — Inspect, test, repair, and replace the components of a horn circuit.
3. Diagnose the cause of constant, intermittent, or no wiper operation; diagnose the cause of wiper speed control and/or park problems; determine needed action.	Unit 10, Assignment Sheet 2 — Diagnose the cause of wiper problems.
4. Inspect and test wiper motor, resistors, park switch, relays, switches, connectors, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 10, Job Sheet 2 — Inspect, test, and replace the components of wiper circuits. Unit 10, Job Sheet 3 — Inspect, test, repair, and replace intermittent (pulsing) wiper controls.
5. Inspect wiper motor transmission linkage, arms, and blades; adjust or replace as needed.	Unit 10, Job Sheet 2 — Inspect, test, and replace the components of wiper circuits.
6. Inspect and test windshield washer motor or pump/relay assembly, switches, connectors, terminals, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 10, Assignment Sheet 3 — Diagnose the cause of windshield washer problems. Unit 10, Job Sheet 4 — Inspect, test, repair, and replace the components of a windshield washer circuit.
7. Inspect and test side-view mirror motors, heater circuit grids, relays, switches, connectors, terminals, and wires, repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 11, Assignment Sheet 2 — Diagnose the cause of heated, lighted, and electrically operated mirror problems. Unit 11, Job Sheet 2 — Inspect, test, repair, and replace the parts of a heated, lighted, and electrically operated mirror.
8. Inspect and test heater and A/C electrical components including: A/C clutches, motors, resistors, relays, switches, connectors, terminals, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 10, Assignment Sheet 4 — Diagnose the cause of heater problems. Unit 10, Assignment Sheet 5 — Diagnose the cause of air conditioning problems. Unit 10, Job Sheet 5 — Inspect, test, repair, and replace the components of a heater circuit. Unit 10, Job Sheet 6 — Inspect, test, repair, and replace the components of an air-conditoning circuit.

NATEF Tasks	MAVCC Tasks
9. Inspect and test auxiliary power outlet, integral fuse, connectors, terminals, and wires; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. Unit 11 Job Sheet 8 — Inspect, test, repair, and replace the parts of a cigar lighter/auxiliary power outlet.
10. Diagnose the cause of slow, intermittent, or no power side window operation; determine needed action.	Unit 11, Assignment Sheet 1 — Diagnose the cause of power window problems.
11. Inspect and test motors, switches, relays, connectors, terminals, and wires of power side window circuits; repair or replace as needed.	Unit 3, Job Sheet 10 — Inspect, test, repair, and replace swtiches, connectors, terminals, and wires of electrical/electronic circuits. Unit 11, Job Sheet 1 — Inspect, test, repair, and replace the parts of a power window.
12. Inspect block heaters; determine needed repairs.	Unit 10, Job Sheet 7 — Inspect, test, repair, and replace the components of an engine block heater.
13. Inspect and test cruise control electrical components; repair or replace as needed.	not covered
14. Inspect and test engine cooling fan electrical control components; repair or replace as needed.	not covered

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Introduction to Diesel Electrical and Electronic Systems

1. Terms and definitions
2. Composition of atoms
3. Electrical charges in atoms
4. Terms relating to electron flow and their definitions
5. Direction that current flows in relation to its electromotive force
6. Two theories on current flow
7. Description of current
8. Two factors that determine the amount of current flowing through a conductor
9. Two types of current and their voltage sources
10. Description of voltage
11. Two sources of voltage in vehicle electrical systems
12. Description of resistance
13. Five factors that influence resistance as current moves through a circuit
14. Two results of resistance as current moves through a conductor
15. Ohm's law
16. Formulas for calculating current, voltage, and resistance in a conductor
17. Description of power

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Introduction to Diesel Electrical and Electronic Systems (continued)

18. Two ways electrical devices can be rated
19. Two common electrical devices that are rated in watts
20. Three kinds of magnets and their definitions
21. Facts about magnets
22. Terms relating to magnetism and electromagnets and their definitions
23. Four properties of electromagnets that make them useful in a vehicle's electrical system
24. Three vehicle electrical components that use electromagnetism

25. Calculate current using Ohm's law
26. Calculate voltage using Ohm's law
27. Calculate resistance using Ohm's law
28. Predict changes in voltage, current, and resistance in a circuit

Unit 2: Understanding Circuits and Circuit Devices

1. Terms and definitions
2. Six circuit elements on an illustration of a basic vehicle electrical circuit
3. Four types of commonly used circuits
4. Two power sources for vehicle electrical circuits
5. Why and where electrical circuits are grounded
6. Wiring diagram symbols that indicate a battery and a ground
7. Common control devices, their illustrations, wiring diagram symbols, current factor controlled, and the type of control each has on voltage or resistance in a circuit
8. Common protection devices, their illustrations and wiring diagram symbols
9. Size categories of blade fuses
10. How fuses, fusible links, and circuit breakers protect the circuits on which they are installed
11. Common loads, their illustrations, wiring diagram symbols, and the form of energy into which each converts current

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 2: Understanding Circuits and Circuit Devices (continued)

12. How a device that is electronic is different from a device that is electric
13. P-type semiconductors and N-type semiconductors
14. Advantages and disadvantages of using eletronic devices as circuits
15. Common electronic circuit devices, their illustrations, wiring diagram symbols, and functions in a circuit
16. Common conductors, their illustrations and wiring diagram symbols
17. Four types of material that are commonly used as insulators in vehicle electrical systems
18. Purpose of a wire shield
19. Three purposes of wiring hardware
20. Common circuit features and their wiring diagram symbols
21. Types of wiring diagrams

22. Explain what the color bands found on resistors represent, and use the color bands on a resistor to determine its resistance value
23. Determine correct replacement fuses
24. Use wire color and circuit identification codes to locate circuit information
25. Use wiring diagrams to locate information about circuits
26. Use knowledge of electric/electronic theory and circuit devices to predict changes in current, voltage, and resistance in a series circuit
27. Inspect, test, and replace spike suppression diodes/resistors

Unit 3: Developing Basic Diagnosis and Repair Skills

1. Terms and definitions
2. Types of common circuits and their electrical characteristics
3. Common problems with electrical circuits (types, symptoms, causes)
4. Types of electrical diagnostic instruments (names and illustrations, usage, calibrated vs. tested requirements)
5. Steps in electrical troubleshooting
6. Steps in soldering
7. Guidelines for soldering

8. Identify types of circuits and circuit devices on a circuit
9. Perform calculations using units of electrical measurement
10. Prepare to measure current, voltage, resistance, and frequency with a multimeter
11. Calculate resistance in sample circuits
12. Calculate current in sample circuits
13. Calculate voltage drop in sample circuits
14. Calculate voltage in sample circuits
15. Calibrate and make functionality tests on electrical diagnostic instruments
16. Check electrical/electronic circuits with jumper cables
17. Check electrical circuits with a test light

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 3: Developing Basic Diagnosis and Repair Skills (continued)

18. Check voltage in electrical/electronic circuits with a multimeter
19. Check voltage drops in electrical/electronic circuits with a multimeter
20. Check current flow in electrical/electronic circuits and components with a multimeter
21. Check continuity and resistance in electrical/electronic circuits and components with a multimeter
22. Find shorts, grounds, opens, and high resistance problems in electrical/electronic circuits
23. Tin a soldering iron or gun
24. Inspect, test, repair, and replace switches, connectors, temrinals, and wires of electrical/electronic circuits
25. Inspect, test, and replace fusible links, circuit breakers, and fuses

Unit 4: Understanding Vehicle Computer Controls

1. Terms and definitions
2. Functions of the basic components of a computer system
3. Common computers (microprocessors) in a vehicle
4. Types of sensors
5. Types of actuators
6. Analog and digital signals
7. Serial data transfer and parallel data transfer
8. Flow of data through a simplified computer system
9. Ways to retrieve diagnostic information from vehicle computers
10. SAE fault code identifiers

11. Demonstrate how a potentiometer functions as a sensor
12. Interpret SAE fault code identifiers
13. Use a DVOM to measure reference voltage output from the electronic control module
14. Access vehicle fault codes using the vehicle's computerized diagnostic system; determine needed repairs

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 5: Battery Diagnosis and Servicing

Related Information: What the Student Should Know

1. Terms and definitions
2. Battery service tools
3. Five functions of the battery
4. Types of vehicle batteries and their descriptions
5. Ratings of batteries and their descriptions
6. Factors affecting correct battery selection
7. Safety rules for working with batteries
8. Connecting batteries in series, parallel, and series-parallel

Application: What the Student Should Be Able to Do

9. Evaluate factors in selecting the appropriate battery for a vehicle
10. Maintain and restore electronic memory functions
41. Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold-downs
12. Make a battery state-of-charge test
13. Make a battery capacity (load) test
14. Determine battery state-of-charge using an open circuit voltage test
15. Slow and fast charge a battery
16. Diagnose parasitic (key-off) battery drain problems
17. Connect batteries in series, parallel, and series-parallel
18. Jump-start a vehicle

Unit 6: Starting Systems Diagnosis and Repair

1. Terms and definitions
2. Types of starting aids
3. Parts of a starting system and descriptions of their functions
4. Major parts of a starting motor
5. Component parts and descriptions of their functions
6. Steps in a starting system operation
7. Conversion of electrical energy in mechanical energy
8. How a starting motor is kept running
9. Types of starter field circuits
10. Types of starter field circuits and current flow
11. Types of starting motor switches
12. Engaging starter drives

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 6: Starting Systems Diagnosis and Repair (continued)

13. Types of electromagnetic or lever shift drives
14. Operation of a series-parallel switch
15. Operation of a transformer-rectifier unit
16. Starting system test
17. Starting system test equipment and their connections

18. Diagnose starting system problems
19. Make a no-load starter current draw test
20. Make starter circuit voltage drop tests
21. Inspect, test, and repair or replace switches, connectors, and wires of starter control circuits
22. Inspect, test, and replace starter relays and solenoids
23. Remove and replace starter

Unit 7: Charging Systems Diagnosis and Repair

1. Terms and definitions
2. Purpose of a charging system, an alternator, and charging system output tests
3. Alternator charging circuit components and functions
4. Major parts of an alternator
5. Construction of stator windings
6. Types of alternator circuits
7. Characteristics of a brushless alternator
8. Operation of a brushless alternator
9. Operation of a transistorized regulator
10. Safety rules for working with alternator charging circuits
11. Names of charging system tests with descriptions of the conditions evaluated by the tests
12. Charging system test equipment and their connections

13. Diagnose charging system problems that cause an undercharge, a no-charge, or an overcharge condition
14. Inspect, adjust, and replace alternator drive belts, pulleys, and tensioners
15. Make a charging system output test; determine needed repairs
16. Make a charging circuit voltage drop test; determine needed repairs
17. Test an S.I. series alternator
18. Inspect, repair, or replace connectors and wires of charging circuits
19. Remove, inspect, and replace an alternator

Unit 8: Lighting Systems Diagnosis and Repair

Related Information: What the Student Should Know

1. Parts of a headlight and daytime running lights circuit and descriptions of their functions
2. Parts of a parking lights, taillights, clearance lights and marker lights circuit and descriptions of their functions
3. Parts of a stoplight (brake light) circuit and descriptions of their functions
4. Parts of a turn signal and hazard lights circuit and descriptions of their functions
5. Parts of a backup lights circuit and descriptions of their functions
6. Parts of an instrument lighting circuit and descriptions of their functions
7. Parts of a courtesy lights circuit and descriptions of their functions
8. Parts of a tractor-to-trailer multi-wire connector

Application: What the Student Should Be Able to Do

9. Diagnose the cause of headlights and daytime running lights problems
10. Diagnose the cause of parking lights, clearance lights, and taillights problems
11. Diagnose the cause of stoplight (brake light) problems
12. Diagnose the cause of turn signals and hazard lights problems
13. Diagnose the cause of back-up lights problems
14. Diagnose the cause of instrument lighting problems
15. Diagnose the cause of courtesy lights problems
16. Inspect, replace, and aim headlights/bulbs
17. Inspect, test, and replace light bulbs and test sockets
18. Inspect, test, repair and replace the components of a headlights and daytime running lights circuit
19. Inspect, test, repair and replace the components of a parking light, clearance light and taillight circuit
20. Inspect, test, repair and replace the components of a stoplight (brake light) circuit
21. Inspect, test, repair and replace the components of a turn signal and hazard lights circuit
22. Inspect, test, repair and replace the components of a back-up lights circuit
23. Inspect, test, repair and replace the components of an instrument lighting circuit
24. Inspect, test, repair and replace the components of a courtesy lights circuit
25. Inspect, test, repair and replace the components of tractor-to-trailer lights circuit

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 9: Driver Information Systems Diagnosis and Repair

1. Basic categories of gauges and descriptions of their operations
2. Types of gauges and descriptions of their operations
3. Types of gauge sending units and descriptions of their operation
4. Parts of a gauge circuit
5. Parts of a gauge circuit and descriptions of their functions
6. Parts of an electronic instrument cluster, warning light, indicator light, and driver information circuits
7. Parts of an electronic instrument cluster, warning light, indicator light, and driver information circuits, and descriptions of their functions
8. Types of driver information commonly given by audible warning devices
9. Parts of an audible warning devices circuit
10. Outputs of an audible warning device circuit and descriptions of their functions

11. Diagnose the cause(s) of faulty gauge readings
12. Diagnose the cause(s) of the faulty operation of an electronic instrument cluster, warning light, indicator light, and driver information circuit
13. Diagnose the cause(s) of the faulty operation of audible warning devices
14. Inspect, test, repair, and replace the components of a gauge circuit
15. Inspect, test, repair, and replace the components of an electronic instrument cluster, warning light, indicator light, and driver information circuit
16. Inspect, test, repair, and replace components of audible warning device circuits
17. Inspect, test, replace and calibrate electronic speedometer, odometer, and tachometer circuits

Unit 10: Related Electrical Components

1. Parts of a horn circuit and descriptions of their functions
2. Parts of a wiper circuit
3. Parts of a wiper circuit and descriptions of their functions
4. Parts of a windshield washer circuit
5. Parts of a windshield washer circuit and descriptions of their functions
6. Parts of a heater circuit
7. Parts of a heater circuit and descriptions of their functions
8. Major and secondary components of an expansion valve type A/C system

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 10: Related Electrical Components (continued)

Related Information: What the Student Should Know

9. Parts of an air conditioning circuit and descriptions of their functions
10. Types of engine block heaters and descriptions of their operations

Application: What the Student Should Be Able to Do

11. Diagnose the cause of horn problems
12. Diagnose the cause of wiper problems
13. Diagnose the cause of windshield washer problems
14. Diagnose the cause of heater problems
15. Diagnose the cause of air conditioning problems
16. Inspect, test, repair, and replace the components of a horn circuit
17. Inspect, test, repair, and replace the components of wiper circuits
18. Inspect, test, repair, and replace intermittent (pulsing) wiper controls
19. Inspect, test, repair, and replace the components of a windshield washer circuit
20. Inspect, test, repair, and replace the components of a heater circuit
21. Inspect, test, repair, and replace the components of an air conditioning circuit
22. Inspect, test, repair, and replace the components of an engine block heater

Unit 11: Miscellaneous Electrical Accessories

Related Information: What the Student Should Know

1. Parts of a power window
2. Parts of a power window and descriptions of their functions
3. Parts of a heated, lighted, and electrically operated mirror and descriptions of their functions
4. Parts of an electric door lock
5. Parts of an electric door lock and descriptions of their functions
6. Parts of a keyless and remote lock/unlock device
7. Parts of a keyless and remote lock/unlock device and descriptions of their functions

Instructional/Task Analysis

Unit 11: Miscellaneous Electrical Accessories (continued)

Related Information: What the Student Should Know

8. Parts of an anti-theft system and descriptions of their functions
9. Parts of a sound system
10. Parts of a sound system and descriptions of their functions
11. Parts of an airbag system
12. Parts of an airbag system and descriptions of their functions
13. Steps to take to prevent the accidental deployment of an airbag

Application: What the Student Should Be Able to Do

14. Diagnose the cause of power window problems
15. Diagnose the cause of heated, lighted, and electrically operated mirror problems
16. Diagnose the cause of electric door lock problems
17. Diagnose the cause of radio reception problems

18 Diagnose the cause(s) of the airbag warning light staying on or flashing

19. Inspect, test, repair, and replace the parts of a power window
20. Inspect, test, repair, and replace the parts of a heated, lighted, and electrically operated mirror
21. Inspect, test, repair, and replace the parts of an electric door lock
22. Inspect, test, repair, and replace the parts of anti-theft systems
23. Inspect, test, repair, and replace the parts of a sound system
24. Remove and reinstall audio system components (unit)
25. Inspect, test, repair, and replace the parts of an airbag system
26. Inspect, test, repair, and replace the parts of a cigar lighter/auxiliary power outlet
27. Inspect, test, repair, and replace the parts of a clock

Basic Skills Icons and Classifications

To assist teachers and students in identifying and documenting where academic and workplace skills are being taught, MAVCC has adopted a system that uses icons and a list of specific tasks to identify the skill or skills that are used in each assignment sheet and job sheet.

A matrix for each of the ten broad skill areas has been included in this edition and reflects key elements from *What Work Requires of Schools: A SCANS Report for America 2000,* a 1991 study by the U.S. Department of Labor; *Workplace Basics: The Skills Employers Want,* a three-year study conducted jointly by the American Society for Training and Development (ASTD) and the United States Department of Labor (DOL); and other national and state sources.

Each of the ten broad skill areas—reading, writing, mathematics, science, oral communication, interpersonal or relating, critical thinking, employability, social studies, and technology—is represented by the icon presented below.

Reading Skills

- Reading Comprehension
- Research/Reference
- Functional Reading

Writing Skills

- Language
- Composition
- Research
- Functional Writing

Math Skills

- Operation and Calculation
- Math Application
- Data Analysis and Display
- Functional Math

Basic Skills Icons and Classifications

Science Skills

- General Science
- Life Science
- Physical Science
- Earth Science

Oral Communication Skills

- Oral Presentation
- Listening
- Interactive Communication

Interpersonal or Relating Skills

- General Relating
- Teamwork/Cooperation
- Leadership/Influence

Critical Thinking Skills

- Cognitive Activities

Employability Skills

- Job Search/Selections
- Job Acquisition/Development
- Resource Management
- Job Safety

Social Studies Skills

- Information Analysis
- Social Studies Application
- Functional Social Studies

Technology Skills

- Selection
- Application
- Maintenance/Troubleshooting

Basic Skills Icons and Classifications

When an activity involving one of these basic skills is identified, the corresponding icon is placed in the left-hand margin of the assignment sheet and job sheet. Skills training is further defined by classifying specific skills that are required.

Example:

Unit 1

Introduction to Diesel Electrical and Electronic Systems

Objective 25

Assignment Sheet 1—Calculate Current Using Ohm's Law

Name ______________________ Overall Rating ________

Date ______________________

Evaluation Criteria	Rating
• Completed all problems and showed work	____
• Labeled answers with correct term	____
• Answered a minimum of 12 of the 15 questions correctly per Assignment Sheet 1 answers.	____

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

Any change in current is a result of increased or decreased voltage or increased or decreased resistance. Current does not change unless voltage and/or resistance changes.

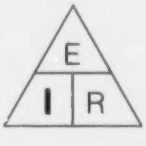
If there is not enough current in a circuit, electrical or electronic components in the circuit will not function properly; a motor might run too slowly or a bulb burn dimly. If there is too much current, circuit components can overheat or burn up, destroying them.

The formula for calculating current is:

> The number of amps is equal to the number of volts divided by the number of ohms.

There are several ways to say the same thing:

- $I = \frac{E}{R}$
- Current is equal to voltage divided by resistance
- $\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$
- $\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$
- $A = \frac{V}{\Omega}$



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Basic Skills Icons and Classifications

Reading Skills

Reading Comprehension

- Gain factual information
- Distinguish fact, opinion, and inference
- Recognize stereotyping and bias
- Recognize propaganda
- Analyze cause and effect
- Draw conclusions
- Make generalizations
- React to written material
- Apply word analysis techniques
- Analyze and apply what has been read to specific task
- Comprehend written information for main ideas
- Determine what information is needed

Research/ Reference

- Select useful resources
- Locate resources
- Find materials in library
- Use standard references
- Use in-book reference tools
- Use audiovisual media
- Use computer database
- Use magazines and newspapers

Functional Reading

- Interpret forms and records
- Follow written instructions
- Interpret graphics and symbols
- Interpret abbreviations/acronyms
- Read aloud
- Use content area vocabulary

Basic Skills Icons and Classifications

	Writing Skills
Language	• Use standard grammar, spelling, and capitalization • State ideas clearly
Composition	• Use complete sentences • Develop preliminary outline • Use topic sentences • Use introductory/closing paragraphs • Compose reports • Compose essays • Proofread and edit • Construct graphics and symbols
Research	• Take notes • Use note cards • Create bibliography • Use footnotes • Outline material
Functional Writing	• Complete forms and records • Write instructions • Write letters • Write job applications • Write resumes • Use word processing • Use computer graphics • Use content area vocabulary

Math Skills

Operation and Calculation

- Round off numbers
- Estimate answers
- Use scientific notations
- Use exponential notations
- Calculate with whole numbers
- Calculate with fractions
- Calculate with decimals
- Convert whole numbers to fractions
- Convert whole numbers to decimals
- Solve numerical expressions
- Solve formulae and equations
- Obtain squares and square roots
- Convert units of measure
- Perform metric calculations

Math Application

- Solve word problems
- Select/apply mathematical formula
- Select/apply mathematical procedure
- Use English and metric measures
- Solve time/rate/distance problems
- Solve ratio/proportion problems
- Solve percent problems
- Apply techniques of scaling
- Apply algebra principles
- Apply geometry principles
- Apply trigonometry principles

Data Analysis and Display

- Interpret charts and tables
- Interpret graphs
- Collect/record data
- Apply sampling techniques
- Apply principles of probability
- Construct charts and tables
- Construct graphs
- Calculate statistics
- Interpret statistics
- Interpret plans/blueprints
- Draw facility to scale

Math Skills (Continued)

Functional Math	• Make measurements • Perform banking transactions • Make change • Solve practical problems • Calculate gross earnings • Solve income/expense problems • Prepare a budget • Calculate interest • Solve interest problems • Calculate sales tax • Determine income tax • Use calculator for computation • Use computer for computation • Use computer spreadsheets • Apply computation skills as they are actually used on the job • Calculate measurements taken from measuring devices • Perform/prepare an inventory • Calculate and compare shipping costs • Prepare financial report

Science Skills

General Science

- Apply computing skills
- Apply scientific method of inquiry
- Conduct experiments
- Investigate science ethics
- Investigate science history
- Investigate/apply economics in technology
- Use scientific instruments
- Investigate/apply technology
- Collect specimens
- Construct model to depict basic concept of ----

Life Science

- Identify/classify living organisms
- Investigate biological history of the earth
- Investigate food chains, webs, pyramids
- Investigate/apply principles of human development
- Investigate/apply principles of genetics/heredity
- Investigate/apply principles of anatomy/physiology
- Investigate health issues
- Observe health code/sanitation requirements

Physical Science

- Analyze/classify matter
- Investigate forms/changes of matter
- Investigate forms/changes of energy
- Investigate/apply chemical properties
- Investigate/apply physical laws

Earth Science

- Investigate physical characteristics of the earth
- Investigate geological history of the earth
- Investigate physical forces acting on the earth
- Solve problems of longitude, latitude, and time zones
- Investigate conservation of physical resources
- Investigate conservation of living resources
- Investigate issues of environmental impact
- Apply science principles to environmental issues

Basic Skills Icons and Classifications

Oral Communication Skills

Oral Presentation

- Make informative presentations
- Make persuasive presentations
- Present personal opinion/viewpoint
- Use good speaking techniques
- Select/use words effectively
- Use effective body language
- Present appropriate appearance
- Integrate audio and/or visual materials into oral presentations
- Adapt presentation to specific audience

Listening

- Apply active listening skills
- Distinguish fact, opinion, and inference
- Draw conclusions/make generalizations
- Analyze/identify point of view

Interactive Communication

- Give/follow oral directions
- Apply questioning techniques
- Conduct/receive interviews
- Analyze/apply nonverbal communication
- Work effectively in a group
- Communicate with clients/customers/patients
- Communicate with coworkers
- Communicate with supervisors
- Communicate with professional colleagues/associates
- Apply telephone etiquette

Interpersonal or Relating Skills

General Relating

- Investigate/apply communication process models
- Analyze/apply nonverbal communication
- Investigate/apply cross-cultural communication
- Interact with coworkers
- Interact with supervisors
- Interact with clients/customers/patients
- Interact with professional colleagues/associates
- Interact with family/friends
- Participate in group activities
- Participate in industrial relations/functions
- Identify personal values/attitudes
- Apply information to life experiences

Teamwork/ Cooperation

- Identify values/attitudes
- Identify needs/drives
- Select/apply appropriate behavior
- Investigate/identify personal styles
- Investigate/identify group/corporate climate
- Give/receive feedback
- Identify hidden purposes
- Investigate/apply group dynamics
- Control undesirable/inappropriate behavior
- Resolve conflicts
- Clarify goals/objectives
- Devise "win/win" situations
- Build consensus
- Generate ideas
- Present point of view

Leadership/ Influence

- Analyze/apply leadership styles
- Analyze/apply management styles
- Obtain confidence of others
- Develop esteem in self/others
- Persuade others
- Analyze/apply motivation techniques
- Provide positive coaching

Critical Thinking Skills

Cognitive Activities

- Collect/record information
- Identify critical elements/issues
- Define a problem
- Identify underlying causes
- Apply a problem-solving model
- Analyze/synthesize information
- Identify/analyze underlying assumptions
- Draw conclusions
- Predict results/outcomes
- Identify/evaluate consequences
- Identify/develop alternatives
- Evaluate alternatives
- Select an alternative
- Devise a solution
- Create a finished product
- Apply intuitive thinking techniques
- Transfer knowledge/training to new situations
- Apply new technology
- Develop an action plan
- Evaluate results/outcomes
- See relationship between two or more ideas, objects, or situations

Employability Skills

Job Search/ Selections

- Analyze personal occupational aptitudes/preferences
- Investigate employment prospects of a career field/occupation
- Investigate training requirements for a career field/occupation
- Investigate benefits of a career field/occupation
- Compare/evaluate career options
- Analyze impact of work on individual and family life

Job Acquisition/ Development

- Develop personal career path
- Locate appropriate jobs
- Analyze duties/requirements/benefits of specific job
- Master specific job task/procedure
- Complete job-related applications
- Write a letter of application
- Write personal resume
- Interview for a job
- Apply business etiquette
- Practice good work habits/attitudes
- Practice good personal presentation
- Develop self confidence/esteem
- Develop effective leadership
- Deal effectively with supervisors
- Deal effectively with coworkers
- Deal effectively with professional colleagues/associates
- Deal effectively with customers/clients/patients
- Follow established rules, regulations, and policies
- Promote the goals and values of the organization
- Exert a high level of effort and perseverance towards goal attainment
- Set high standards for self in completion of a task

Resource Management

- Complete task in timely manner
- Determine cost, time, and resources to complete a task
- Perform routine tasks related to equipment operation and/or maintenance

Job Safety

- Demonstrate safe use of tools, equipment, and supplies
- Observe safety rules
- Wear safety equipment
- Follow safety procedures
- Demonstrate proper use of safety device

Basic Skills Icons and Classifications

Social Studies Skills

Information Analysis

- Collect/record data
- Interpret graphical information
- Construct graphical information
- Interpret maps/globes
- Interpret statistical information
- Analyze/interpret demographic information
- Distinguish trends and predicts impact of actions on systems operations

Social Studies Application

- Investigate/apply U.S. history
- Investigate/apply world history
- Investigate/apply U.S. geography
- Investigate/apply world geography
- Investigate/apply principles of government/politics
- Investigate/apply principles of economics
- Investigate/apply principles of ethics
- Investigate/apply principles of sociology
- Investigate/apply cross-cultural studies

Functional Social Studies

- Practice responsible personal economics
- Prepare a personal budget
- Use credit responsibly
- Practice good work ethics
- Participate in industrial relations
- Interact with people of different races/cultures
- Investigate/participate in government
- Investigate/apply American legal practices
- Select/use sources of information on current events
- Analyze current events
- Analyze consumer issues
- Analyze social issues
- Analyze conservation/ecology issues
- Analyze social impact of science/technology
- Analyze economic impact of science/technology
- Understand how social, organizational, and technological systems work and operate effectively

Technology Skills

Selection	• Choose procedures, tools, or equipment including computers and related technologies that will produce the desired results
Application	• Demonstrate the proper procedures for setting up and operating equipment, including computers and their programming systems
Maintenance/ Troubleshooting	• Perform maintenance on equipment, including computers and other technologies • Identify and correct problems with equipment • Report damaged or broken equipment to appropriate individual

Basic Skills Matrix

Unit 1–Introduction to Diesel Electrical and Electronic Systems

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
25	Calculate current using Ohm's law (A.S. 1)	📚	Reading	Functional reading	Follows written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		🔢	Math	Operation and calculation	Round off numbers Calculate with whole numbers Calculate with decimals Solve numerical expressions
				Math application	Solve word problems Select/apply mathematical formula
		⚗	Science	Physical science	Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Apply a problem-solving model
26	Calculate voltage using Ohm's law (A.S. 2)	📚	Reading	Functional reading	Follows written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		🔢	Math	Operation and calculation	Round off numbers Calculate with whole numbers Calculate with decimals Solve numerical expressions
				Math application	Solve word problems Select/apply mathematical formula
		⚗	Science	Physical science	Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Apply a problem-solving model

Basic Skills Matrix

Unit 1–Introduction to Diesel Electrical and Electronic Systems (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
27	Calculate resistance using Ohm's law (A.S. 3)	📚	Reading	Functional reading	Follows written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		🔢	Math	Operation and calculation	Round off numbers Calculate with whole numbers Calculate with decimals Solve numerical expressions
				Math application	Solve word problems Select/apply mathematical formula
		⚗	Science	Physical science	Investigate/apply physical laws
		❓	Critical thinking	Cognitive activities	Apply a problem-solving model
28	Predict changes in voltage, current, and resistance in a circuit (A.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	Physical science	Investigate/apply physical laws
		❓	Critical thinking	Cognitive activities	Predict results/outcomes Identify/evaluate consequences Identify/develop alternatives Evaluate alternatives Select an alternative

Unit 2–Understanding Circuits and Circuit Devices

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
22	Explain what the color bands found on resistors represent, and use the color bands on a resistor to determine its resistance value (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		✏	Writing	Language	Use standard grammar, spelling, and capitalization
				Composition	Use complete sentences Proofread and edit
		🔢	Math	Operation and calculation	Calculate with whole numbers Calculate with decimals Solve numerical expressions
		💡	Critical thinking	Cognitive activities	Apply a problem-solving model Analyze/synthesize information Draw conclusions Evaluate alternatives Devise a solution Transfer knowledge to new situations
23	Determine correct replacement fuses (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		✏	Writing	Language	Use standard grammar, spelliing, and capitalization State ideas clearly
				Composition	Use complete sentences Proofread and edit
		🔢	Math	Data analysis and display	Interpret charts and tables
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Apply a problem-solving model Analyze/synthesize information Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge to new situations

Basic Skills Matrix

Unit 2–Understanding Circuits and Circuit Devices (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
24	Use wire color and circuit identification codes to locate circuit information (A.S. 3)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
			Math	Data analysis and display	Interpret charts and tables
			Critical thinking	Cognitive activities	Apply a problem-solving model Analyze/synthesize information Draw conclusions Transfer knowledge to new situations
25	Use wiring diagrams to locate information about circuits (A.S. 4)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
			Critical thinking	Cognitive activities	Apply a problem-solving model Analyze/synthesize information Draw conclusions Transfer knowledge to new situations

Basic Skills Matrix

Unit 2–Understanding Circuits and Circuit Devices (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
26	Use your knowledge of electric/electronic theory and circuit devices to predict changes in current, voltage, and resistance in a series circuit (A.S. 5)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
		✎	Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Apply a problem-solving model Analyze/synthesize information Draw conclusions Predict results/outcomes
27	Inspect, test, and replace spike suppression diodes/resistors (J.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 3–Developing Basic Diagnosis and Repair Skills

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
8	Identify types of circuits and circuit devices on a circuit (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols
		✏	Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
				Composition	Use complete sentences
		🔢	Math	Functional math	Make measurements
		💡	Critical thinking	Cognitive activities	Analyze/synthesize information Draw conclusions
9	Perform calculations using units of electrical measurement (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols
		✏	Writing	Language	Use standard grammar, spelling, and capitalization
				Composition	Use complete sentences
		🔢	Math	Operation and calculation	Convert whole numbers to decimals
				Math application	Select/apply mathematical formula

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
10	Prepare to measure current, voltage, resistance, and frequency with a multimeter (A.S. 3)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols
			Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
				Composition	Use complete sentences
			Math	Functional math	Make measurements
				Math application	Select/apply mathematical formula
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Analyze/synthesize information Draw conclusions
11	Calculate resistance in sample circuits (A.S. 4)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Operation and calculation	Calculate with whole numbers Solve formulae and equations
				Math application	Select/apply mathematical formula
12	Calculate current in sample circuits (A.S. 5)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Operation and calculation	Calculate with whole numbers Solve formulae and equations
				Math application	Select/apply mathematical formula

Basic Skills Matrix

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
13	Calculate voltage drop in sample circuits (A.S. 6)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Operation and calculation	Calculate with whole numbers Solve formulae and equations
				Math application	Select/apply mathematical formula
14	Calculate voltage in sample circuits (A.S. 7)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Operation and calculation	Calculate with whole numbers Solve formulae and equations
				Math application	Select/apply mathematical formula
15	Calibrate and make functionality tests on electrical diagnostic instruments (J.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
			Technology	Application	Demonstrate the proper procedures for setting up and operating equipment
				Maintenance/ troubleshooting	Identify and correct problems with equipment

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
16	Check electrical/ electronic circuits with jumper cables (J.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
17	Check electrical circuits with a test light (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
18	Check voltage in electrical/electronic circuits with a mulitmeter (J.S. 2)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
19	Check voltage drops in electrical/electronic circuits with a multimeter (J.S. 3)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
20	Check current flow in electrical/ electronic circuits and components with a mulitmeter (J.S. 6)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
21	Check continuity and resistance in electrical/electronic circuits and components with a multimeter (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
22	Find shorts, grounds, opens, and high resistance problems in electrical/electronic circuits (J.S. 8)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
23	Tin a soldering iron or gun (J.S. 9)	📚	Reading	Functional reading	Follow written instructions
		💡	Critical thinking	Cognitive activities	Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 3–Developing Basic Diagnosis and Repair Skills (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
24	Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/ electronic circuits (J.S. 10)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
25	Inspect, test, and replace fusible links, circuit breakers, and fuses (J.S. 11)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 4–Understanding Vehicle Computer Controls

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
11	Demonstrate how a potentiometer functions as a sensor. (A.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols
			Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
				Composition	Use complete sentences
			Math	Functional math	Make measurements
			Science	General science	Apply computing skills Conduct experiments Investigate/apply technology
			Critical thinking	Cognitive activities	Collect/record information Analyze/synthesize information
12	Interpret SAE fault codes (A.S. 2)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
			Math	Data analysis and display	Interprets charts and tables
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify/analyze underlying assumptions Draw conclusions

Basic Skills Matrix

Unit 4–Understanding Vehicle Computer Controls (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
13	Use a DVOM to measure reference voltage output from the electronic control module (J.S. 1)		Reading	Reading comprehension	Gain factual information
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions
			Math	Data analysis and display	Collect/record data Interpret statistics
			Science	General science	Use scientific instruments Interpret statistics
			Critical thinking	Cognitive activities	Analyze/synthesize information
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
			Technology	Application	Demonstrate the proper procedures for setting up and operating equipment
14	Access vehicle fault codes using the vehicle's computerized diagnostic system; determine needed repairs (J.S. 2)		Reading	Reading comprehension	Gain factual information
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions
			Math	Data analysis and display	Collect/record data Interpret statistics
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Analyze/synthesize information
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
9	Evaluate factors in selecting the appropriate battery for a vehicle (A.S. 1)		Reading	Reading comprehension	Gain factual information Draw conclusions
				Research/ reference	Select useful resources Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Science	General science	Investigate/apply technology
			Critical thinking	Cognitive activities	Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Device a solution Transfer knowledge/training to new situations
10	Maintain and restore electronic memory functions (J.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
			Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
			Critical thinking	Cognitive activities	Identify/evaluate consequences Transfer knowledge/ training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Development self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
11	Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold downs (J.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Identify/analyze underlying assumptions Draw conclusions Create a finished product Transfer knowledge to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Development self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
12	Make a battery state-of-charge test (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary Interpret abbreviations/acronyms
		🔢	Math	Operation and calculation	Calculate with decimals Perform metric calculations
				Math application	Select/apply mathematical procedure
				Data analysis and display	Interpret charts and tables Interpret statistics
				Functional math	Make measurements Solve practical problems
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
				Physical science	Investigate/apply chemical properties Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Make generalizations Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
13	Make a battery capacity (load) test (J.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary Interpret abbreviations/acronyms
		🔢	Math	Math application	Use English and metric measures
				Data analysis and display	Interpret charts and tables Collect/record data
				Functional math	Make measurements
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
				Physical science	Investigate/apply chemical properties Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
14	Determine battery state-of-charge using an open circuit voltage test (J.S. 5)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary Interpret abbreviations/acronyms
			Math	Math application	Use English and metric measures
				Data analysis and display	Interpret charts and tables Collect/record data
				Functional math	Make measurements
			Science	General science	Use scientific instruments Investigate/apply technology
				Physical science	Investigate/apply chemical properties Investigate/apply physical laws
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
15	Slow and fast charge a battery (J.S. 6)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary Interpret abbreviations/acronyms
			Math	Operation and calculation	Calculate with decimals
				Math application	Select/apply mathematical procedure
				Data analysis and display	Interpret charts and tables Collect/record data
				Functional math	Make measurements
			Science	General science	Use scientific instruments Investigate/apply technology
				Physical science	Investigate/apply chemical properties Investigate/apply physical laws
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Create a finished product Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Diagnose parasitic (key-off) battery drain problems (J.S. 7)	●	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		●	Math	Data analysis and display	Collect/record data
				Functional math	Make measurements
		●	Science	General science	Use scientific instruments Investigate/apply technology
		●	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		●	Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
17	Connect batteries in series, parallel, and series-parallel (J.S. 8)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret graphics and symbols
		🔢	Math	Data analysis and display	Construct graphics and symbols
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply chemical properties
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Create a finished product Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Basic Skills Matrix

Unit 5–Battery Diagnosis and Servicing (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
18	Jump start a vehicle (J.S. 9)	📚	Reading	Reading comprehension	Gain factual information
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
		?	Critical thinking	Cognitive activities	Collect/record information Identify/evaluate consequences Create a finished product Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self-confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Following safety procedures

Basic Skills Matrix

Unit 6–Starting Systems Diagnosis and Repair

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
18	Diagnose starter system problems (A.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Critical thinking	Cognitive activities	Identify underlying causes Apply a problem-solving model Draw conclusions Identify/develop alternatives Evaluate results/outcomes
19	Make a no-load starter current draw test (off vehicle) (J.S. 1)		Reading	Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Math	Functional math	Make measurements Solve practical problems
			Critical thinking	Cognitive activities	Collect/record information Identify underlying causes Apply a problem-solving model Draw conclusions Identify/evaluate consequences Evaluate results/outcome Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 6–Starting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
20	Make starter circuit voltage drop tests (J.S. 2)		Reading	Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Math	Functional math	Make measurements Solve practical problems
			Interpersonal or relating skills	General relating	Interact with coworkers
			Critical thinking	Cognitive activities	Collect/record information Identify underlying causes Apply a problem-solving model Draw conclusions Identify/evaluate consequences Evaluate results/outcome Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
21	Inspect, test, and repair or replace switches, connectors, and wires or starter control circuits (J.S. 3)		Reading	Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Math	Functional math	Make measurements Solve practical problems
			Critical thinking	Cognitive activities	Collect/record information Identify underlying causes Apply a problem-solving model Draw conclusions Identify/evaluate consequences Evaluate results/outcome Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 6–Starting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
22	Inspect, test, and replace starter relays and solenoids (J.S. 4)		Reading	Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Math	Functional math	Make measurements Solve practical problems
		?	Critical thinking	Cognitive activities	Collect/record information Identify underlying causes Apply a problem-solving model Draw conclusions Identify/evaluate consequences Evaluate results/outcome Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
23	Remove and replace a starter (J.S. 5)		Reading	Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Math	Functional math	Make measurements
		?	Critical thinking	Cognitive activities	Identify underlying causes Apply a problem-solving model Draw conclusions Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 7–Charging Systems Diagnosis and Repair

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
13	Diagnose charging system problems that cause an undercharge, a no-charge, or an overcharge condition (A.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use standard reference tools
				Functional reading	Follow written instructions Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
14	Inspect, adjust, and replace alternator drive belts, pulleys, and tensioners (J.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 7–Charging Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	Task	Icon	Skill	Sub Skill	Description
15	Make a charging system output test; determine needed repairs (J.S. 2)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 7–Charging Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Making a charging system voltage drop test; determine needed repairs (J.S. 3)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 7–Charging Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
17	Test an S.I. series alternator (J.S. 4)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 7–Charging Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
18	Inspect, repair, or replace connectors and wires of charging circuits (J.S. 5)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
19	Remove, inspect, and replace an alternator (J.S. 6)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Select useful resources Use standard references
				Functional reading	Follow written instructions Interpret graphics and symbols Interpret abbreviations/acronyms Use content area vocabulary
			Math	Data analysis and display	Interpret charts and tables
			Critical thinking	Cognitive activities	Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 8 – Lighting Systems Diagnosis and Repair

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
9	Diagnose the cause of headlights and daytime running lights problems (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
10	Diagnose the cause of parking lights, clearance lights, and taillights problems (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
11	Diagnose the cause of stoplight (brake light) problems (A.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Basic Skills Matrix

Unit 8 – Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
12	Diagnose the cause of turn signals and hazard lights problems (A.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
13	Diagnose the cause of back-up lights problems (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
14	Diagnose the cause of instrument lighting problems (A.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Unit 8 – Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
15	Diagnose the cause of courtesy lights problems (A.S. 7)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
16	Inspect, replace, and aim headlights/ bulbs (J.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Use content area vocabulary
		🔢	Math	Functional math	Make measurements
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions Predict results/outcomes Evaluate results/outcomes Transfer knowledge/training to new situations
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 8 - Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
17	Inspect, test, and replace light bulbs and test sockets (J.B. 2)	📚	Reading	Reading comprehension	Gain factual information Draw conclusions
				Functional reading	Follow written instructions
		?	Critical thinking	Cognitive activities	Identify underlying causes Analyze/synthesize information Draw conclusions Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
18	Inspect, test, repair, and replace the components of a headlights and daytime running lights circuit (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 8 – Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
19	Inspect, test, repair, and replace the components of a parking light, clearance light, and taillight circuit (J.S. 4)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
20	Inspect, test, repair, and replace the components of a stoplight (brake light) circuit (J.S. 5)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 8 – Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
21	Inspect, test, repair, and replace the components of a turn signal and hazard lights circuit (J.S. 6)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
22	Inspect, test, repair, and replace the components of a back-up lights circuit (J.S. 5)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 8 - Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
23	Inspect, test, repair, and replace the components of a instrument lighting circuit (J.S. 8)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
24	Inspect, test, repair, and replace the components of a courtesy lights circuit (J.S. 9)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 8 - Lighting Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
25	Inspect, test, repair, and replace the components of tractor-to-trailer lights circuit (J.S. 10)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 9 – Driver Information Systems Diagnosis and Repair

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
11	Diagnose the cause(s) of faulty gauge readings (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		🔢	Math	Data analysis and displays	Interpret charts and tables
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Define a solution Transfer knowledge/training to new situations
12	Diagnose the cause(s) of the faulty operation of an electronic instrument cluster, warning light, indicator light, and driver information circuit (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		🔢	Math	Data analysis and displays	Interpret charts and tables
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Define a solution Transfer knowledge/training to new situations

Basic Skills Matrix

Unit 9 - Driver Information Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
13	Diagnose the cause(s) of the faulty operation of audible warning devices (A.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		🔢	Math	Data analysis and displays	Interpret charts and tables
		⚗	Science	General science	Investigate/apply technology
				Physical science	Investigate/apply physical laws
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Define a solution Transfer knowledge/training to new situations
14	Inspect, test, repair, and replace the components of a gauge circuit (J.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify underlying causes Analyze/synthesize information Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 9 – Driver Information Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
15	Inspect, test, repair, and replace the components of an electronic instrument cluster, warning light, indicator light, and driver information circuit (J.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify underlying causes Analyze/synthesize information Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
16	Inspect, test, repair, and replace the components of audible warning device circuits (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify underlying causes Analyze/synthesize information Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 9 - Driver Information Systems Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
17	Inspect, test, repair, and calibrate electronic speedometer, odometer, and tachometer circuits (J.S. 4)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
			Science	General science	Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify underlying causes Analyze/synthesize information Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 10 – Related Electrical Components

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
11	Diagnose the cause of horn problems (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
12	Diagnose the cause of wiper problems (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
13	Diagnose the cause of windshield washer problems (A.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Basic Skills Matrix

Unit 10 - Related Electrical Components (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
14	Diagnose the cause of heater problems (A.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
15	Diagnose the cause of air conditioning problems (A.S. 5)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Unit 10 – Related Electrical Components (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Inspect, test, repair, and replace the components of a horn circuit (J.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
17	Inspect, test, and replace the components of wiper circuits (J.S. 2)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
			Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 10 – Related Electrical Components (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
18	Inspect, test, repair, and replace intermittent (pulsing) wiper controls (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
19	Inspect, test, and replace the components of a windshield washer circuit (J.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 10 - Related Electrical Components (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
20	Inspect, test, repair, and replace the components of a heater circuit (J.S. 5)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
21	Inspect, test, and replace the components of an air conditioning circuit (J.S. 6)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 10 - Related Electrical Components (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
22	7Inspect, test, repair, and replace the components of an engine block heater (J.S. 7)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Interpret abbreviations/acronyms Use content area vocabulary
		🧪	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 11 – Miscellaneous Electrical Accessories

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
14	Diagnose the cause of power window problems (A.S. 1)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
15	Diagnose the cause of heated, lighted, and electrically operated mirror problems (A.S. 2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
16	Diagnose the cause of electric door lock problems (A.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Basic Skills Matrix

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
17	Diagnose the cause of radio reception problems (A.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphs and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative
18	Diagnose the cause(s) of the airbag warning light staying on or flashing (A.S. 5)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphs and symbols Use content area vocabulary
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Select an alternative

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
19	Inspect, test, repair, and replace the parts of a power window (J.S. 1)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
20	Inspect, test, repair, and replace the parts of a heated, lighted, and electrically operated mirror (J.S. 2)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
21	Inspect, test, repair, and replace the parts of an electric door lock (J.S. 3)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
22	Inspect, test, repair, and replace the parts of anti-theft systems (J.S. 4)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
23	Inspect, test, repair, and replace the parts of a sound system (J.S. 5)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
24	Remove and reinstall audio system components (J.S. 6)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Basic Skills Matrix

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
25	Inspect, test, repair, and replace the parts of an airbag system (J.S. 7)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures
26	Inspect, test, repair, and replace the parts of a cigar lighter/auxiliary power outlet J.S. 8)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Interpret graphics and symbols Use content area vocabulary
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Unit 11 – Miscellaneous Electrical Accessories (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
27	Inspect, test, repair, and replace the parts of a clock (J.S. 9)		Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Interpret forms and records Follow written instructions Use content area vocabulary
			Science	General science	Use scientific instruments Investigate/apply technology
		?	Critical thinking	Cognitive activities	Identify critical elements/issues Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes Identify/evaluate consequences Transfer knowledge/training to new situations
			Employability	Job acquisition/ development	Master specific job task/procedure Develop self confidence/esteem
				Job safety	Demonstrate safe use of tools, equipment, and supplies Follow safety procedures

Tools, Equipment, and Materials List

- Alternator
- Amp meter – high capacity
- Apron – rubber
- Anticorrosion compound
- Baking soda
- Batteries – 6- and 12-volt
- Battery cables
- Battery carrier or lifting strap
- Battery charger
- Battery pliers
- Battery terminal clamp puller
- Battery terminal cleaning tool
- Belt tension gauge
- Booster power supply
- Brushes
  - Wire
  - Scrub
  - Light socket cleaning
- Carbon pile
- Clock, watch, or timer
- Cloth
- Crimping tool
- Data link connector
- Diagnostic instruments
  - Jumper wires
  - 12-volt test light
  - Self-powered test light
  - Multimeter
  - Volt-ohm meter
  - Tractor/trailer lighting tester
- Distilled water
- Flashlight
- Fuses
- Fusible links
- Gloves – rubber
- Heat shrink
- Hydrometer or refractometer
- Jumper cables
- Knife
- Light bulb removal pliers
- Memory keeper
- Scan tool or laptop computer with appropriate software
- Safety glasses
- Service manuals – assorted
- Solder – rosin core
- Soldering iron
- Splice clip
- Sponge
- Switches – assorted
- Tachometer
- Tape
  - Electrical
  - Masking
- Technician's common hand tools
- Terminal – assorted
- Thermometer – glass
- Torque wrench
- Wheel chocks
- Wire stripping tool

Other tools, equipment and materials may be required to complete job sheets.

Introduction to Diesel Electrical and Electronic Systems

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—The Basic Atom (Objective 2)
TM 2—Simple and Complex Atoms (Objective 2)
TM 3—Electrical Charges of Atomic Particles (Objective 3)
TM 4—Bound and Free Electrons (Objective 4)
TM 5—Balanced and Unbalanced Atoms (Objective 4)
TM 6—Electron Movement in a Wire (Objective 5)
TM 7—Three Types of Atomic Structure (Objective 5)
TM 8—Effect of Wire Length on Resistance (Objective 13)
TM 9—Effect of Wire Diameter on Resistance (Objective 13)
TM 10—Ohm's Law in Wheel Expression (Objective 15)
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TM 18—Magnetic Field and Flux Density (Objective 22)
TM 19—Magnetic Reluctance (Objective 22)
TM 20—The Principle of Electromagnetic Induction (Objective 22)

Suggested Activities

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Teaching Suggestions

- Demonstrate magnetic lines of force by using iron filings and a conductor.
- Demonstrate how to make an electromagnet using 5′ of electrical wire, a soft iron bar, and a 1.5-volt battery.
- Demonstrate how two like magnet poles repel each other and two different poles attract each other.
- Demonstrate how to measure voltage, resistance, frequency and current on a simple circuit with a digital multimeter.
- Show direct and alternating current waves with an oscilloscope.
- Show voltage spikes on a simple circuit with an oscilloscope or locking multimeter.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Academic and Workplace Skills for M/H Truck Technicians.* Herndon, VA: National Automotive Technicians Education Foundation (NATEF), 1995.
- *ASE Automotive Technician Tests—The Official 1996 ASE Preparation Guide.* Herndon, VA: National Institute for Automotive Service Excellence, 1996.
- Chrysler Corp., *Basic Electricity: Student Reference Book*, 1989.
- Chrysler Corp., *Electricity and Electronics: Section 1—Fundamentals.*
- Derato, Frank C. *Automotive Electrical and Electronic Systems.* Westerville, OH: Gregg Division, Glencoe/McGraw-Hill, 1990.
- Ford Motor Co. *Automotive Electronics Reference Book*, 1991.
- Ford Motor Co. *Basic Automotive Electronics—Part One*, 1981.
- Fowler, Richard J. *Electricity (Principles and Applications).* OH: Glencoe/McGraw-Hill, 1994.
- General Motors. *Electrical Theory and Basic Circuitry*, 1991.
- General Motors. *Specialized Electronics Training (SET)*, 1995.

- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual* 2nd ed. Albany, NY: Delmar Publishers, 1997.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems).* Albany, NY: Delmar Publishers, 2000.
- Norman, Ian, et al. *Heavy Duty Truck Systems,* 2nd ed. Albany, NY: Delmar Publishers, 1996.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics.* Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Calculate Current Using Ohm's Law

1. 2 amps
2. 1.5 amps
3. .4 amps
4. 2.4 amps
5. .2 amps
6. 6.67 amps
7. .3 amps
8. 25 amps
9. 3.2 amps
10. 1.29 amps
11. 1 amp
12. 3.75 amps
13. 2.52 amps
14. 2.16 amps
15. .85 amps

Assignment Sheet 2

Calculate Voltage Using Ohm's Law

1. 6 volts
2. 24 volts
3. 12 volts
4. 24 volts
5. 6 volts
6. 12 volts
7. 6 volts
8. 11.9 volts
9. 12 volts
10. 6 volts
11. 12 volts
12. 6.01 volts
13. 12 volts
14. 23.97 volts
15. 6 volts

Answers to Assignment Sheets

Assignment Sheet 3

Calculate Resistance Using Ohm's Law

1. 3 ohms
2. 3 ohms
3. .4 ohms
4. 1.5 ohms
5. 24 ohms
6. 4.8 ohms
7. 1.33 ohms
8. 120 ohms
9. .6 ohms
10. .63 ohms
11. 5 ohms
12. .8 ohms
13. 40 ohms
14. 16 ohms
15. .2 ohms

Assignment Sheet 4

Predict Changes in Voltage, Current, and Resistance in a Circuit

1. a
2. b
3. b
4. a
5. a
6. b
7. b
8. a
9. a
10. a
11. a
12. b
13. a
14. a
15. b
16. b
17. a
18. a
19. b
20. b
21. a
22. b
23. b
24. a
25. a
26. b
27. b
28. b
29. a
30. b

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms related to basic electrical principles to their correct definitions. Write the correct numbers in the blanks.

1. Atom
2. Circuit
3. Compound
4. Conductor
5. Element
6. Insulator
7. Matter
8. Molecule
9. Semiconductor
10. Voltage drop

_____ a. A substance that prevents the passage of an electric charge

_____ b. A substance that transmits an electric charge

_____ c. A substance that neither transmits an electric charge well nor prohibits the passage of an electric charge well

_____ d. The smallest unit of an element that still has all the characteristics of that element

_____ e. Anything that occupies space and can be perceived by one or more of our senses

_____ f. A form of matter that cannot be reduced to a simpler substance by normal chemical means

_____ g. A series of electrically or electromagnetically connected components or devices capable of conducting electric current

_____ h. The voltage lost or consumed as current moves through resistance

_____ i. The smallest particle into which a compound can be divided without changing its chemical and physical properties

_____ j. A substance made up of two or more elements that are joined by chemical forces

Written Test

Objective 2

Identify true statements about atoms by selecting the true one from a pair of similar statements. Select the true statements from the pairs of statements below and write the letter corresponding to the true statement on the blank line.

_____ a. 1. All the atoms of an element have the same number of protons.
2. Atoms of the same element can have different numbers of protons.

_____ b. 1. Each orbit (shell) can hold any number of electrons.
2. Each orbit (shell) can only hold a limited number of electrons.

_____ c. 1. Every element has a different atomic number.
2. Similar elements have the same atomic number.

_____ d. 1. Protons and neutrons are located in the nucleus.
2. Neutrons and electrons are located in the nucleus.

_____ e. 1. Electrons rotate around the nucleus in random orbits (or shells).
2. Electrons rotate around the nucleus in fixed orbits (or shells).

_____ f. 1. The number of orbits (shells) an atom has depends on how many protons it has.
2. The number of orbits (shells) an atom has depends on how many electrons it has.

_____ g. 1. The central core of an atom is called the neutron.
2. The central core of an atom is called the nucleus.

_____ h. 1. The outermost orbit of electrons of any atom is called the valence orbit (shell).
2. The innermost orbit of electrons of any atom is called the valence orbit (shell).

_____ i. 1. An element's atomic number is equal to the number of protons in the nucleus.
2. An element's atomic number is equal to the number of electrons in its orbits (shells).

_____ j. 1. Two particles make up an atom.
2. Three particles make up an atom.

Objective 3

Identify true statements about the electrical charges in atoms by placing a T in the blank in front of true statements and placing an F in the blank in front of false statements.

_____ a. Electrons are held in orbit around the nucleus by the strong attraction between the negatively (–) charged electrons and the positively (+) charged protons.

_____ b. Like electrical charges repel each other.

_____ c. An atom is held together by a balance between centrifugal force and the magnetism within it.

_____ d. Electrons remain evenly spaced in the orbits (shells) because their like charges repel each other.

_____ e. Unlike electrical charges attract each other.

_____ f. Magnetic force prevents the electrons from moving in toward the protons.

_____ g. Neutrons do not have an electrical charge, but have the ability to cancel the repelling force between the protons, thus holding the nucleus together.

_____ h. Protons have a positive charge and neutrons have a negative charge.

_____ i. Like electrical charges attract each other.

_____ j. An atom is held together by a balance of electrical charges within it.

Objective 4

Match terms relating to electron flow to their definitions. Write the correct numbers in the blanks.

1. Balanced atom
2. Bound electrons
3. Electromotive force
4. Electron drift
5. Free electrons
6. Unbalanced atom

_____ a. Electrons in an atom's valence orbit (shell)

_____ b. An atom which has the same number of protons as it has electrons

_____ c. Electrons moving from one atom to another

_____ d. An atom which has a different number of protons than it has electrons

_____ e. A force which causes electrons to move out of their orbit

_____ f. Electrons in an atom's inner orbits(s)

Written Test

Objective 5

State what direction electric current flows in relation to its electromotive force.

____

Objective 6

Distinguish between the conventional and electron theories of current flow by placing a "c" next to the definition of the conventional theory, and an "e" next to the definition of the electron theory.

_____ a. This theory states that current flows from the negative terminal, through conductors, back to the positive terminal.

_____ b. This theory states that current flows from the positive terminal, through conductors, back to the negative terminal.

Objective 7

Describe current.

a. Write the definition of the term current.

____

____

b. Name the unit of measurement used to measure current.

____

____

c. Write the abbreviation for the unit of measurement used to measure current.

____

d. Write the symbol used in mathematical formulas to signify current.

____

e. Name the measurement instrument used to measure current.

____

Objective 8

Name the two factors that determine the amount of current flowing through a conductor.

____

____

Objective 9

Match the two types of current to their definitions. Write the correct numbers in the blanks.

1. Alternating current
2. Direct current

_____ a. Current which flows first in one direction, then in the other direction

_____ b. Current which flows in only one direction

Objective 10

Describe voltage.

a. Write the definition of the term voltage.

____

____

____

b. Name the unit of measurement used to measure voltage.

____

c. Write the abbreviation for the unit of measurement used to measure voltage.

____

d. Write the symbol used in mathematical formulas to signify voltage.

____

e. Name the measurement instrument used to measure voltage.

____

Objective 11

List three sources of voltage for a vehicle's electrical systems.

- ______________________________
- ______________________________
- ______________________________

Objective 12

Describe resistance.

a. Write the definition of the term resistance.

____

____

b. Name the unit of measurement used to measure resistance.

____

c. Write the abbreviation for the unit of measurement used to measure resistance.

____

d. Write the symbol used in mathematical formulas to signify resistance.

____

e. Name the measurement instrument used to measure resistance.

____

Written Test

Objective 13 List five factors that influence resistance as current moves through a circuit.

- ________________________________
- ________________________________
- ________________________________
- ________________________________
- ________________________________

Objective 14 List two results of resistance as current moves through a conductor.

- ________________________________
  ____
- ________________________________
  ____

Objective 15 State Ohm's law

a. Definition

____

____

____

b. Mathematical formula

Objective 16 Write the formulas for calculating the current, voltage, and resistance in a conductor.

a. Current: ____________________________

b. Voltage: ____________________________

c. Resistance: __________________________

Objective 17

Describe power.

a. Write the definition of the term power.

____

____

b. Name the unit of measurement used to measure power.

____

c. Write the abbreviation for the unit of measurement used to measure power.

____

Objective 18

List two ways electrical devices can be rated.

- ______________________________
- ______________________________

Objective 19

List two common electrical devices that are rated in watts.

- ______________________________
- ______________________________

Objective 20

Match three kinds of magnets to their definitions. Write the correct numbers in the blanks.

1. Electromagnet   2. Natural magnet   3. Permanent magnet

_____ a. A man-made magnet that only has magnetic qualities when influenced by an electrical field

_____ b. A man-mad magnet that keeps its magnetic qualities indefinitely

_____ c. A magnetic material that occurs naturally

Objective 21

Identify true statements about magnets by writing the number corresponding to the true statement on the blank line.

_____ a. 1. Magnetic force can be seen.
2. Magnetic force is invisible

_____ b. 1. Some conductors carrying electricity create a magnetic field.
2. All conductors carrying electricity create a magnetic field.

_____ c. 1. Most magnets have poles usually called the north pole and the south pole.
2. All magnets have poles usually called the north pole and the south pole.

_____ d. 1. Electricity can be used to produce magnetism.
2. Electricity cannot be used to produce magnetism.

_____ e. 1. Like poles repel; unlike poles attract.
2. Unlike poles repel; like poles attract.

_____ f. 1. Some materials magnetize easily; other materials do not magnetize at all.
2. All materials can be magnetized to some degree.

_____ g. 1. Magnetism can be used to produce electricity.
2. Magnetism cannot be used to produce electricity.

_____ h. 1. A magnetic field can be insulated.
2. A magnetic field cannot be insulated.

Objective 22

Match terms relating to magnetism and electromagnets to their definitions. Write the correct numbers in the blanks.

1. Electromagnetic induction
2. Flux density
3. Flux lines
4. Magnet
5. Magnetic field
6. Magnetic flux
7. Magnetic permeability
8. Magnetic reluctance
9. Magnetism

_____ a. How easily magnetic forces pass through a substance

_____ b. The strength of the magnetic force operating in a magnetic field

_____ c. Imaginary lines that define a magnetic field

_____ d. The number of flux lines per inch

_____ e. An object that is surrounded by a magnetic field and has the capacity to attract certain materials

_____ f. The process of creating voltage using magnets

_____ g. How difficult it is for magnetic forces to pass through a substance

_____ h. The force exerted by magnets

_____ i. The space around a magnet where the force of the magnet can be detected

Objective 23

List four properties of electromagnets that make them useful in electrical systems.

- ____
- ____
- ____
- ____

Objective 24

List three electrical components that use electromagnetism.

- ____
- ____
- ____

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 6
b. 4
c. 9
d. 1
e. 7
f. 5
g. 2
h. 10
i. 8
j. 3

Objective 2

a. 1
b. 2
c. 1
d. 1
e. 2
f. 2
g. 2
h. 1
i. 1
j. 2

Objective 3

a. T
b. T
c. F
d. T
e. T
f. F
g. T
h. F
i. F
j. T

Objective 4

a. 5
b. 1
c. 4
d. 6
e. 3
f. 2

Objective 5

Current moves away from its electromotive force.

Objective 6

a. "e"
b. "c"

Objective 7

a. Current is a flow of electric charge moving through a conductor.
b. ampere or amp
c. A
d. I
e. ammeter or multimeter

Objective 8

Answer should include both of the following in any order:

- voltage
- resistance

Objective 9

a. 1
b. 2

Answers to Written Test

Objective 10

a. Voltage is the difference in electrical potential between two points in a circuit.
b. volt
c. V
d. E
e. voltmeter or multimeter

Objective 11

Answer should include both of the following in any order:

- battery
- alternator/generator

Objective 12

a. Resistance is opposition to the flow of current in a conductor.
b. ohm
c. Ω
d. R
e. ohmmeter or multimeter

Objective 13

Answer should include all of the following in any order:

- Type of material conducting the current
- Length of the conductor
- Diameter of the conductor
- Temperature of the conductor
- Physical condition of the conductor

Objective 14

Answer should include both of the following in any order:

- Voltage always drops after encountering resistance.
- Some of the electrical energy changes to another form of energy such as heat, light, or motion after encountering resistance.

Objective 15

a. It takes one volt of electrical pressure to push one ampere of electrical current through one ohm of electrical resistance.

b. $I = \frac{E}{R}$

Objective 16

a. $I = \frac{E}{R}$

b. $E = I \times R$

c. $R = \frac{E}{I}$

Objective 17

a. Power is the rate at which work is done.
b. watt
c. W

Objective 18

Answer should include both of the following in any order:

- ohms of resistance
- watts of power capacity

Objective 19

Answers may include the following or any other electrical devices that are rated in watts.

- resistors
- small lamps

Objective 20

a. 1
b. 3
c. 2

Objective 21

a. 2
b. 2
c. 2
d. 1
e. 1
f. 1
g. 1
h. 2

Objective 22

a. 7
b. 6
c. 3
d. 2
e. 4
f. 1
g. 8
h. 9
i. 5

Objective 23

Answer should include all of the following in any order:

- They can be turned on and off.
- They can achieve a very high level of magnetic force.
- The strength of their magnetic force can be adjusted.
- They can be used to increase, decrease, and control voltage.

Objective 24

Answers may include the following (in any order) or any three other electrical components that use electromagnetism:

- electric motors
- solenoids
- relays

Unit 1

Introduction to Diesel Electrical and Electronic Systems

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 and 2.

☐ 4. **Read** Student Supplement 1, "Matter and Atoms."

Optional

☐ 5. **Research** Online lessons regarding Matter, and Electricity and Magnetism.
Visit http://ippex.pppl.gov/ippex/PhysicsModules.html as one of your resources.

Note: This internet address is case sensitive and must be typed exactly as written above. Additional downloads, available at this internet site, may be required to view the material.

☐ 6. **Study** Information Sheet, Objectives 3 through 6.

☐ 7. **Read** Student Supplement 2, "How Electricity is Created."

☐ 8. **Study** Information Sheet, Objectives 7 through 14.

☐ 9. **Read** Student Supplement 3, "Current, Voltage, and Resistance."

☐ 10. **Study** Information Sheet, Objectives 15 and 16.

☐ 11. **Read** Student Supplement 4, "Ohm's Law."

Learning Activities Sheet

☐ 12. **Do** Assignment Sheet 1, "Calculate Current Using Ohm's Law."

☐ 13. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, repeat Steps 10 and 12.

☐ 14. **Do** Assignment Sheet 2, "Calculate Voltage Using Ohm's Law."

☐ 15. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, repeat Steps 10 and 14.

☐ 16. **Do** Assignment Sheet 3, "Calculate Resistance Using Ohm's Law."

☐ 17. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, repeat Steps 10 and 16.

☐ 18. **Do** Assignment Sheet 4, "Predict Changes in Voltage, Current, and Resistance in a Circuit."

☐ 19. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 20. If the evaluation is not satisfactory, repeat Steps 10 and 18.

☐ 20. **Study** Information Sheet, Objectives 17 through 19.

📖 ☐ 21. **Read** Student Supplement 5, "Energy and Electricity."

☐ 22. **Study** Information Sheet, Objectives 20 through 24.

📖 ☐ 23. **Read** Student Supplement 6, "Magnets."

☐ 24. **Study** Student Supplement 7, "Magnetism and Electricity."

☐ 25. **Check** With instructor for any additional assignments to be completed.

☐ 26. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 27. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Teacher Supplement 1—Internet Resources

Increasingly, today's diesel shops are becoming more and more technologically advanced, and there are many reasons why today's electrical/electronic technicians need to be computer savvy. Computers can control almost every aspect of vehicle operations, diagnostic equipment must be designed to interface what that equipment, and technicians must be trained to operate and program both vehicle and diagnostic computers. The Internet can provide numerous resources a technician can access to obtain specifications, find parts, and solve problems by talking to experts.

Engine, Tractor, and Parts and Equipment Manufacturers

The manufacturers listed below provide a multitude of information and services on their websites. Some of these sites contain service bulletins, on-line service manuals, specification sheets, application and installation manuals, diagnostic software, parts information, and question and answer forums.

- Freightliner Trucks – www.freightlinertrucks.com
- Detroit Diesel – www.detroitdiesel.com
- Cummins – www.cummins.com
- Caterpillar – www.caterpillar.com
- International – www.navistarinternational.com
- Mack Trucks – www.macktrucks.com
- Kenworth – www.kenworth.com
- Peterbilt – www.peterbilt.com
- Volvo – www.volvotrucks.com
- Mercedes-Benz – www.mercedes-benz.com
- John Deere – www.johndeere.com
- Delco-Remy – www.delcoremy.com
- Bendix – www.bendix.com
- Battery Council International—www.batterycouncil.org
- AC Delco—www.acdelco.com
- Exide Batteries—www.exideworld.com

- Interstate Batteries—www.interstatebatteries.com
- Vermont Safety Information Resources—www. hazard.com/msds

Other

These websites provide access to certification requirements, job outlook, trucking industry news, maintenance procedures, and other related links

- National Automotive Technicians Education Foundation (NATEF) – www.natef.org

  Contains information pertaining to medium/heavy-duty truck technician certification.

- National Institute of Automotive Service Excellence (ASE) – www.asecert.org

  Contains information pertaining to medium/heavy-duty truck technician certification.

- Occupational Outlook – stats.bls.gov/oco/ocos182.htm

  Provides information on the employment, training, job outlook and earnings for diesel mechanics and service technicians.

- American Trucking Association – www.truckline.com

  The American Trucking Association is the national trade association of the trucking industry and home to The Maintenance Council (TMC). Here, you can access TMC's recommended procedures.

- Truck Net – www.truck.net

  This site provides links to various areas in the industry such as education, computer hardware and software, magazines, news, manufacturers, and round table discussions.

- U.S. Department of Transportation – www.dot.gov

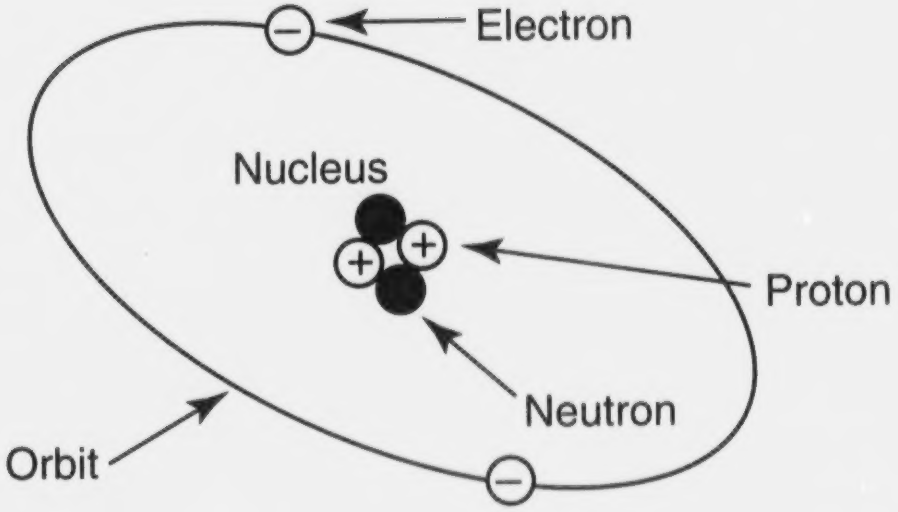
  Links to Department of Transportation, Federal Highway Administration, and Federal Highway Traffic Safety Administration standards and regulations.

- IPPEX Interactive Physics Modules–contains lessons on Electricity and Magnetism

  http://ippex.pppl.gov/ippex/PhysicsModules.html

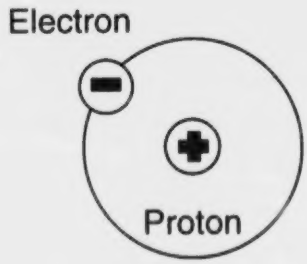
  Note: This internet address is case sensitive and must be typed exactly as written above. Additional downloads, available at this internet site, may be required to view the material.

The Basic Atom


Electron
Nucleus
Proton
Neutron
Orbit

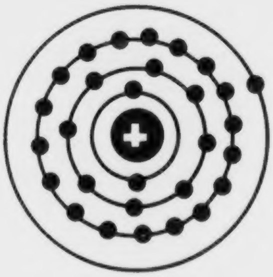
134

Simple and Complex Atoms



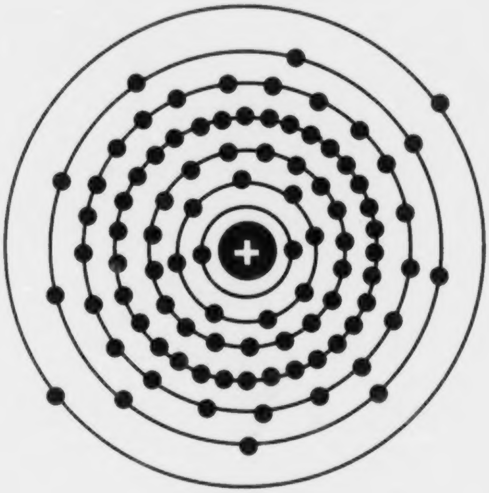
Hydrogen Atom

1 Electron
1 Proton



Copper Atom

29 Electrons
29 Protons

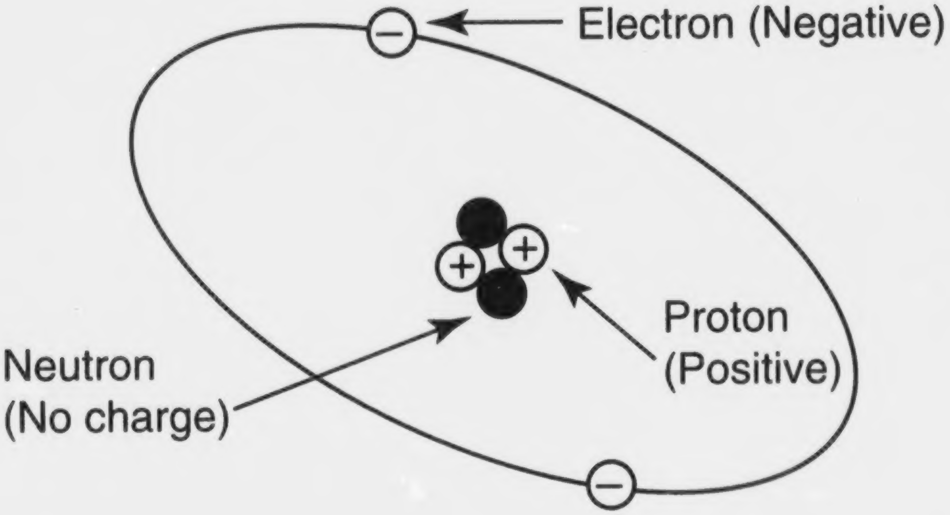


Uranium Atom

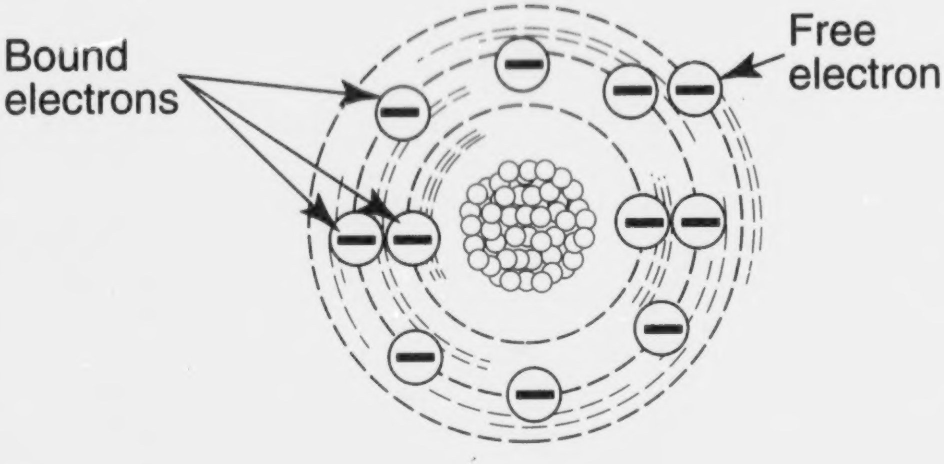
92 Electrons
92 Protons

Note: Count the Number of Electrons in the Outer Ring of the Atom.

Electrical Charges of Atomic Particles


Electron (Negative)
Proton
(Positive)
Neutron
(No charge)

Bound and Free Electrons


Bound electrons
Free electron

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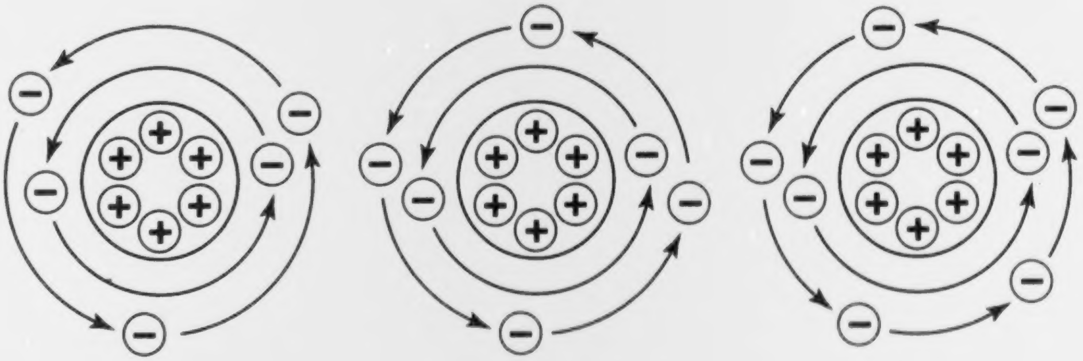
Balanced and Unbalanced Atoms



Unbalanced
(Positive ion)
(5 electrons,
6 protons)

Balanced
(6 electrons,
6 protons)

Unbalanced
(Negative ion)
(7 electrons,
6 protons)

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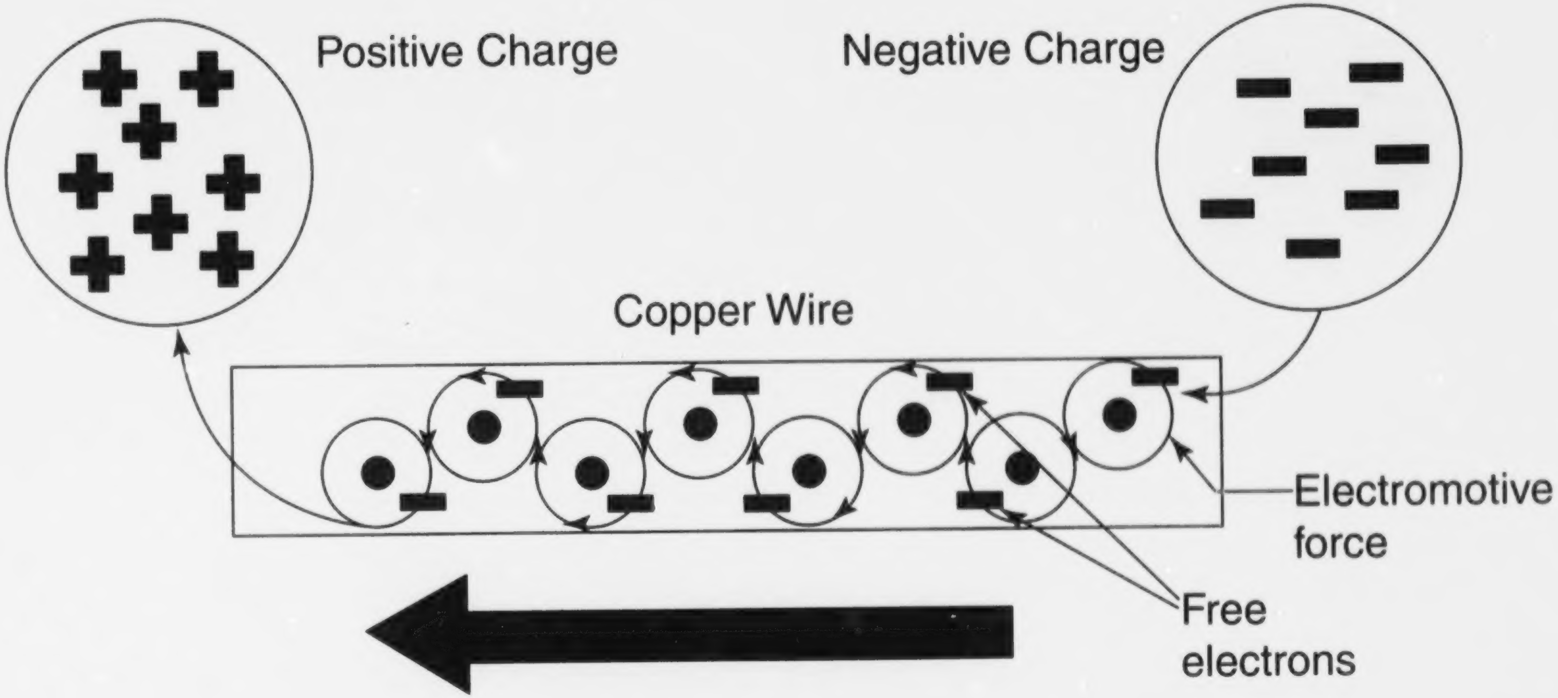
Electron Movement in a Wire



Positive Charge

Negative Charge

Copper Wire

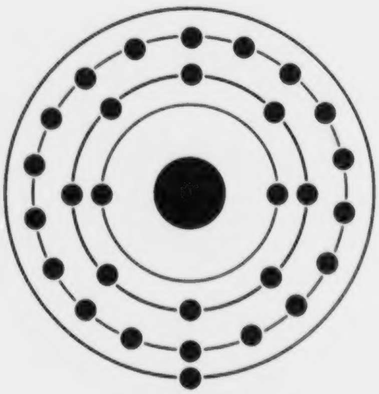
Electromotive force

Free electrons

Electron Flow

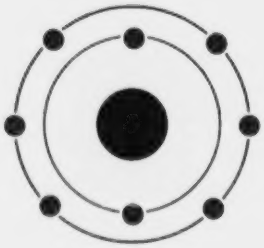
Three Types of Atomic Structure

Conductors



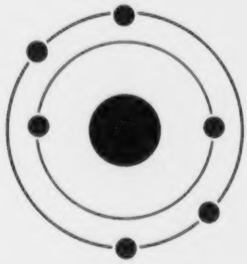
1-3 Electrons
in outer orbit

Insulators



5-8 Electrons
in outer orbit

Semiconductors



4 Electrons
in outer orbit

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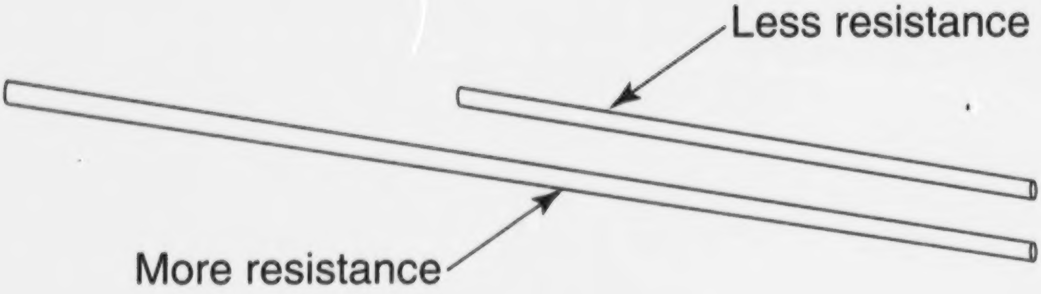
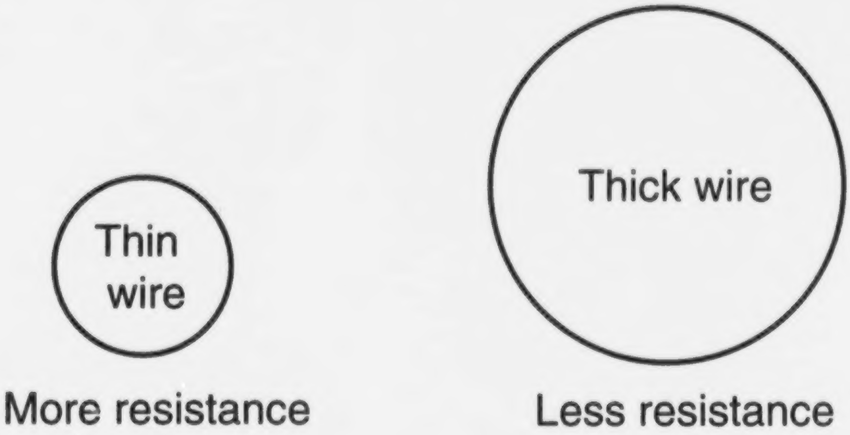
Effect of Wire Length on Resistance


Less resistance
More resistance

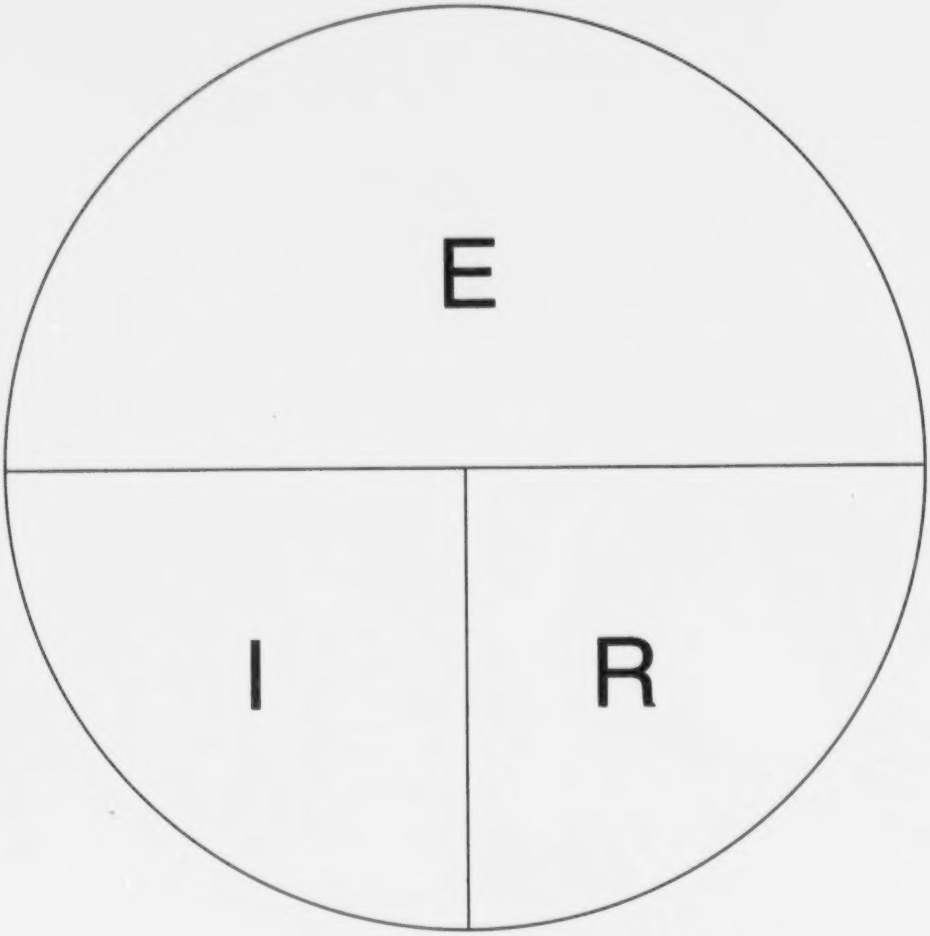
142

TM 8

Effect of Wire Diameter on Resistance


Thin wire
More resistance
Thick wire
Less resistance

Ohm's Law in Wheel Expression



I = Amps
R = Ohms
E = Volts

TM 10

Formula for Calculating Current

$$I = \frac{E}{R}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

To find the **current** (amps),
divide the **voltage** (volts)
by the **resistance** (ohms).

Formula for Calculating Voltage

$E = I \times R$

Volts = Amps x Ohms

To find the **voltage** (volts),
multiply the **current** (amps)
by the **resistance** (ohms).

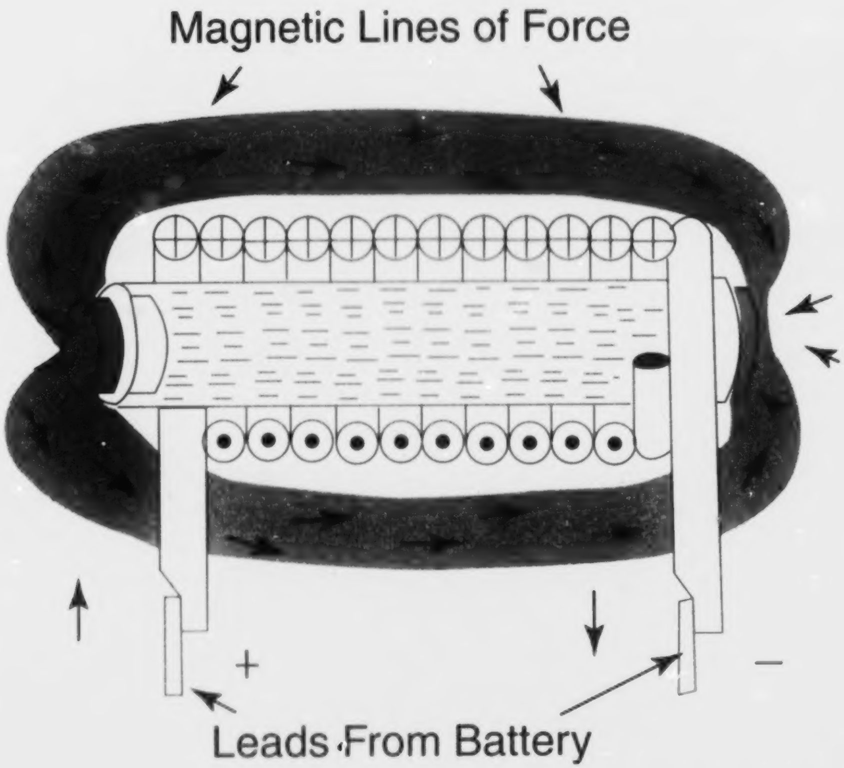
Formula for Calculating Resistance

$$R = \frac{E}{I}$$

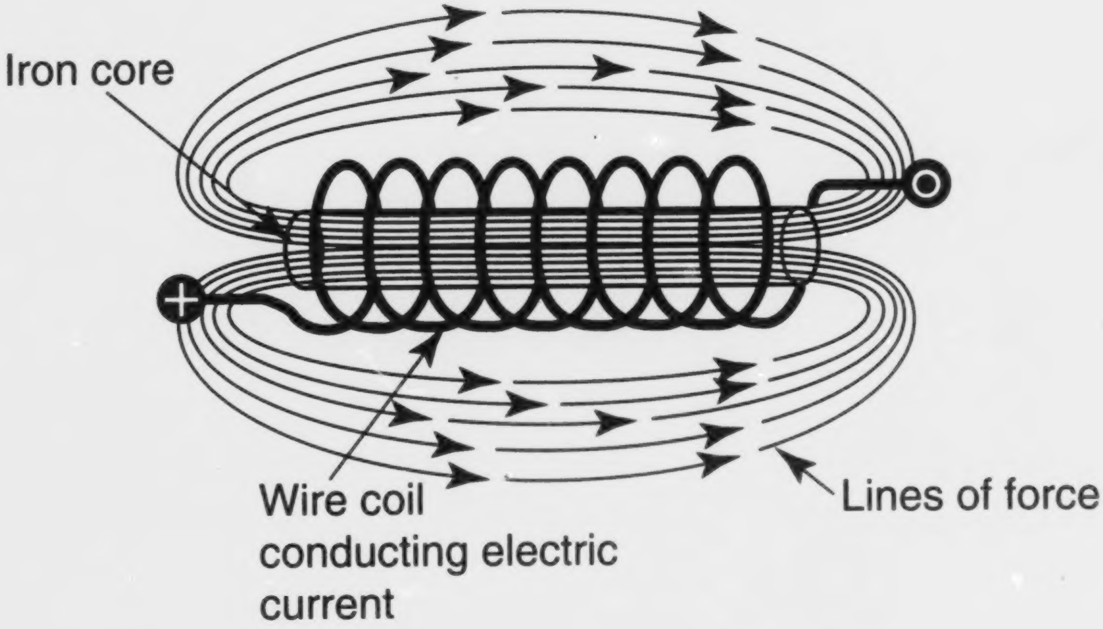
$$\text{Ohms} = \frac{\text{Volts}}{\text{Amps}}$$

To find the **resistance** (ohms),
divide the **voltage** (volts)
by the **current** (amps).

Magnetism and Field of Force


Magnetic Lines of Force
+
−
Leads From Battery

An Electromagnet


Iron core
+
Wire coil conducting electric current
Lines of force

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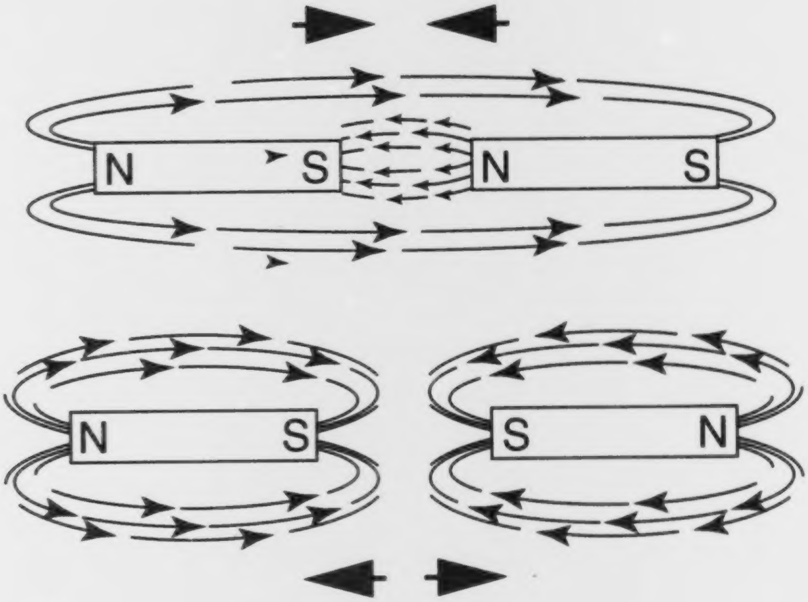
Magnetic Attraction and Repulsion



Unlike poles attract

Like poles repel

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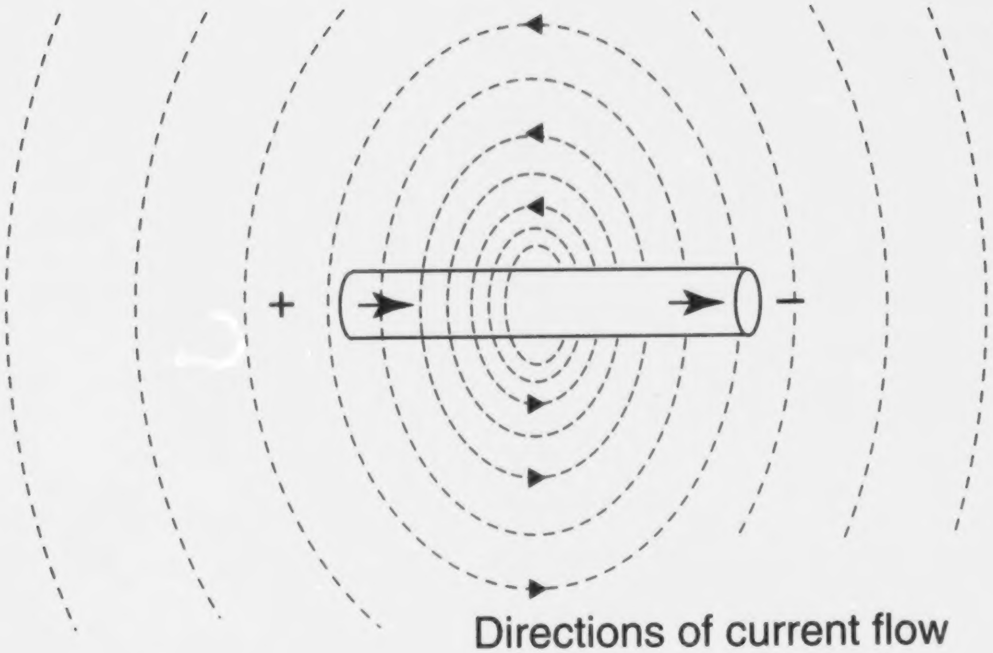
Magnetic Field Around a Straight Conductor



Directions of current flow

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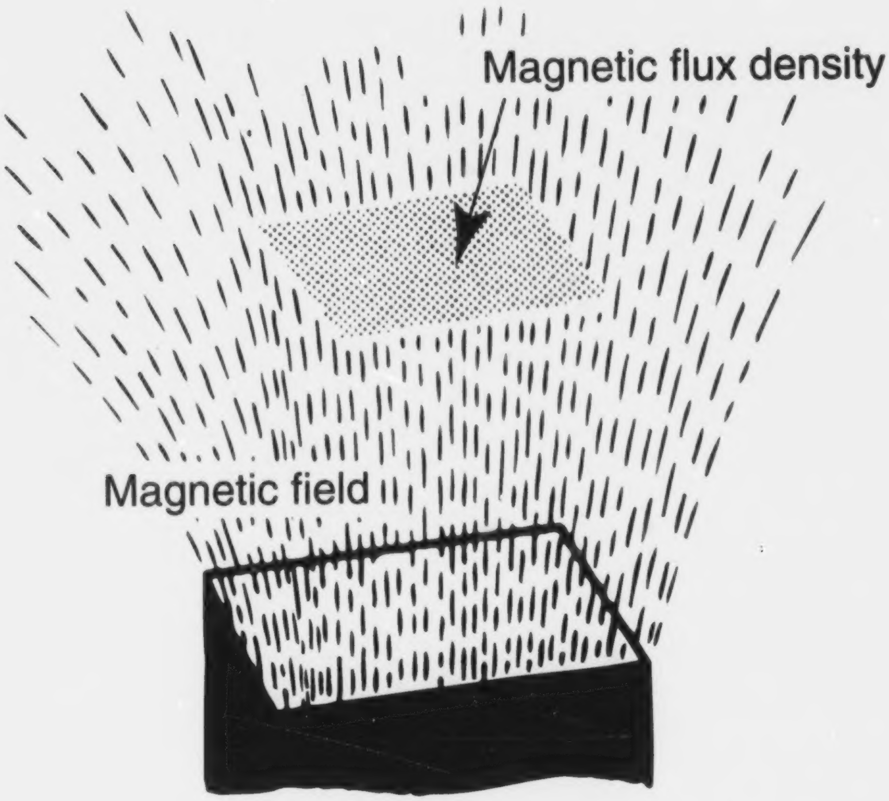
Magnetic Field and Flux Density


Magnetic flux density
Magnetic field

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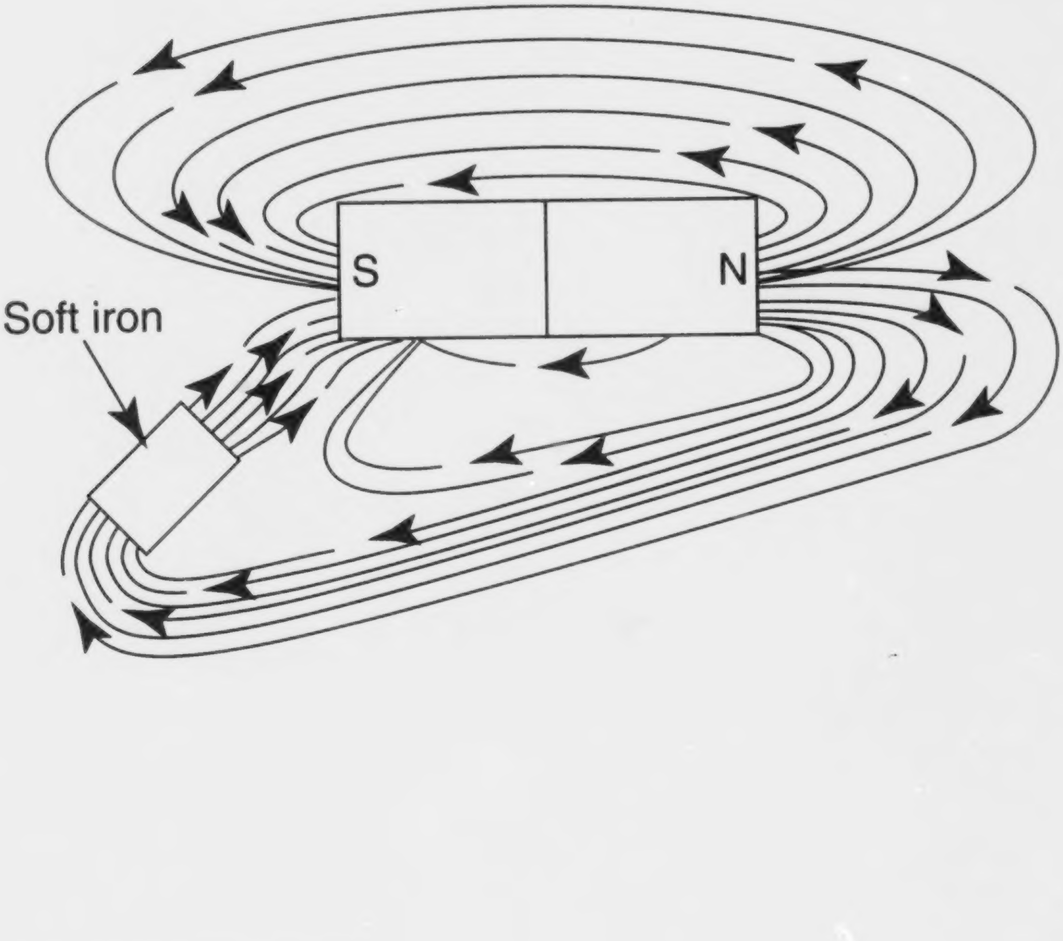
Magnetic Reluctance



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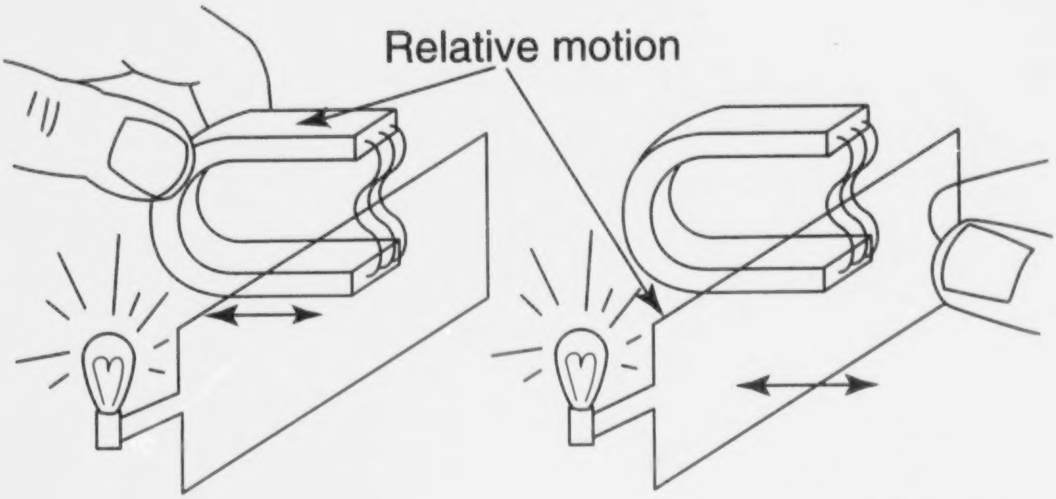
The Principle of Electromagnetic Induction



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Student Page

Student Components

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4—Use Wiring Diagrams to Locate Information About Circuits 2–95
5—Use Your Knowledge of Electric/Electronic Theory and Circuit Devices to Predict Changes in Current, Voltage, and Resistance in a Series Circuit 2–101

Job Sheet

1—Inspect, Test, and Replace Spike Suppression Diodes/Resistors 2–105

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Basic Vehicle Circuit (Objective 2)
TM 2—Series Circuit (Objective 3)
TM 3—Parallel Circuit (Objective 3)
TM 4—Series-Parallel Circuit (Objective 3)
TM 5—Logic Circuit (Objective 3)
TM 6—Symbols and Ground Circuit (Objectives 5 and 6)
TM 7—SPST, SPDT, and MPMT Switches (Objective 7)
TM 8—Pressure, Mercury, and Temperature Switches (Objective 7)
TM 9—Relay, Flasher, and Capacitor (Objective 7)
TM 10—Fixed and Stepped Resistors (Objective 7)
TM 11—Rheostat and Potentiometer (Objective 7)
TM 12—Glass and Blade Fuse (Objective 8)
TM 13—Fusible Link (Objective 8)
TM 14—Circuit Breaker (Objective 8)
TM 15—Size Categories of Blade Fuses (Objective 9)
TM 16—Lamp, Motor, and Gauge (Objective 11)
TM 17—Buzzer, Horn, and Heated Mirror Grid (Objective 11)
TM 18—Cigar Lighter and Solenoid (Objective 11)
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TM 20—Diodes (Objective 15)
TM 21—Diode Rectifier Bridge, Transistor, and Phototransistor (Objective 15)
TM 22—Thermistor, Darlington Pair, and Thyristor (Objective 15)
TM 23—Wire, Terminal, and Connector (Objective 16)
TM 24—Component Case, Socket, Circuit Board, and Vehicle Body and Frame (Objective 16)
TM 25—Ground Strap and Wire Shield (Objectives 16 and 18)
TM 26—Tubing, Sleeve, Retainer, and Clip (Objective 19)
TM 27—Tie Strap, Boot, and Wiring Harness (Objective 19)
TM 28—Components (Objective 20)
TM 29—Wires (Objective 20)
TM 30—Wiring (Objective 20)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Set up samples of series, parallel, series-parallel, and logic circuits to demonstrate the differences between them.

- Look at examples of batteries and generators on several vehicles.
- Show students different grounding points on a vehicle to demonstrate how the body/frame of the vehicle acts as a ground for circuits.
- Use Teacher Supplement 1 to present examples of other types of wiring diagram symbols.
- Present students with actual examples of control and protection devices that are commonly found in most vehicles, and demonstrate how each one operates. If possible, show examples of where each one is located on a vehicle.
- Show examples of different types of fuses, fusible links, and circuit breakers. Show how they look when they are new and how to tell when they are burned out.
- Demonstrate how to determine fuse ratings using actual fuses. Then have each student demonstrate their ability to do the same.
- Show examples of electronic circuit devices and where each may be located on a vehicle.
- Show examples of conductors and wiring hardware, and how and when each are used.
- Look at different types of insulating materials used on vehicles and demonstrate the proper method of inspecting insulation.
- Gather examples of the different types of wiring and demonstrate how to read each one.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

Suggested Activities

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Academic & Workplace Skills for M/H Truck Technicians.* Herndon, VA: National Automotive Technicians Education Foundation (NATEF), 1995.

- *ASE Automotive Technician Tests—The Official 1996 ASE Preparation Guide.* Herndon, VA: National Institute for Automotive Service Excellence, 1996.

- Chrysler Corp., *Electrical Diagnosis 1, Student Workbook*, 1994.
- Chrysler Corp., *Electrical Diagnosis 2, Student Workbook*, 1994.
- Chrysler Corp., *Electricity and Electronics: Section 1—Fundamentals.*
- Chrysler Corp., *Electricity and Electronics: Section 3—Starting and Charging.*
- Chrysler Corp., *Electricity and Electronics: Section 4—Wiring and Accessories.*
- Denton, Tom. *Automobile Electrical & Electronic Systems.* Warrendale, PA: SAE International, 1995.
- Duffy, James E. *Auto Electricity and Electronics Technology*, Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1998.
- Duffy, James E. *Auto Electricity, Electronics, Computers*, South Holland, IL: The Goodheart-Willcox Company, Inc., 1989.
- Erjavec, Jack and Robert Scharff. *Automotive Technology—A Systems Approach*, Albany, NY: Delmar Publishers, 1992.
- Ford Motor Co. *Automotive Electronics Reference Book*, 1991.
- Ford Motor Co. *Basic Automotive Electronics—Part Three*, 1982.
- Ford Motor Co. *Basic Automotive Electronics—Part Four*, 1983.
- Ford Motor Co. *Electrical Systems*, 1988.
- Ford Motor Co. *Ford Technical Self-Study Program: Unit 4 Electrical Systems*, 1989.
- Ford Motor Co. *How to Read and Understand Electrical Diagrams*, 1984.
- General Motors. *Applied Automotive Electronics*, 1991.
- General Motors. *Body Electrical*, 1987.
- General Motors. *Electrical Theory and Basic Circuitry*, 1991.
- General Motors. *Maintenance-Free Batteries, Charging and Starting Systems*, 1987.
- General Motors. *Technical Specifications—Batteries, Charging &Cranking*, 1987.

- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual,* 2nd ed. Albany, NY: Delmar Publishers, 1996.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual,* 2nd ed. Albany, NY: Delmar Publishers, 1996.
- Ribbins, William B. *Understanding Automotive Electronics,* 3rd ed., Indianapolis, IN: Howard W. Sams & Co., 1988.
- Santini, Al. *Automotive Electricity and Electronics,* 3rd ed., Albany, NY: Delmar Publishers, 1988.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems),* Albany, NY: Delmar Publishers, 2000.
- Norman, Ian, et al. *Heavy Duty Truck Systems,* 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics.* Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Explain What the Color Bands Found on Resistors Represent, and Use the Color Bands on a Resistor to Determine Its Resistance Value

1. 56,000 Ω ± 2%
2. 1,000 Ω ± 1%
3. ± 10%
4. .7Ω ± 5%
5. 590 Ω ± 20%
6. 2.6 Ω ± 1%
7. 4,800 Ω ± 2%
8. .09 Ω ± 20%
9. 4,000 Ω ±20%
10. brown, gray, black, gold
11. No—It has the wrong resistance value. It is too low—it will burn up.
12. Yes—It has the correct resistance value. And even though its size tells you that the resistor's watts rating is different than the original resistor, because the number of watts is higher than the old resistor, it will work correctly on the circuit.
13. black, red, black, gold
14. 63,000 Ω ± 2%
15. gray, brown, red

Answers to Assignment Sheets

Assignment Sheet 2

Determine Correct Replacement of Fuses

1. blue
2. The answer should include all of the following in any order:
   - from the color of the fuse
   - on the top of the fuse itself
   - on the cover of the fuse box
   - in the vehicle's owner manual
3. in a fuse box under the instrument panel
4. 40 amps
5. No—even though the fuse has the same amp rating, it is the wrong size.
6. Look on the metal terminal on the end of the fuse
7. No—the fuse will blow before the load(s) on the circuit can carry out its function.
8. No—the circuit is designed to function with no more than 10 amps of current; the other circuit devices on the circuit will be damaged if the current is above 10 amps, even though the new fuse will not blow until the current reaches more than 25 amps.
9. blue and yellow
10. You wouldn't be able to install the fuse in the fuse box.

Assignment Sheet 3

Use Wire Color and Circuit Identification Codes to Locate Circuit Information

1. dark green with a violet tracer
2. The wire is a 10-gauge tan wire with an orange tracer. It is located on the exterior lighting circuit, branch 2B.
3. dark blue with a white stripe
4. brown
5. brown
6. 1mm^2
7. G106
8. 52

9. brown, yellow, light blue, orange

10. 3mm^2 black

Assignment Sheet 4

Using Wiring Diagrams to Locate Information About Circuits

1. SPST switch

2. battery, starter relay, automatic transmission neutral start & back-up lamp switch, ignition switch, and field coil starter motor

3. red, 12 gauge

4. S2

5. MPMT switch

6. Yes—there is a diode in the starter relay

7. 196

8. purple

9. connectors J & G

10. connector A & terminal 2, connector B & terminal 2, connector E & terminal A, and connector J

11. 320

12. white wire, connector D & terminal C, and connector H & terminal B

13. connector A & terminal 4, connector B & terminal 4, and connector E & terminal D

14. 12034051

15. aux relay, N/O C1 contact for N/C C2 coil (starter relay), and N/C C1 contact for alternator

16. 220° F

17. 10 psi

18. push starter button which energizes C1 coil (aux relay), which closes N/O C1 contact, which energizes C2 coil (starter relay) that closes N/O C2 contact, which energizes starter motor.

19. C1 coil energizes, opening N/C C1 contact, de-energizing the alternator

20. 30 amp

Answers to Assignment Sheets

Assignment Sheet 5

Use Your Knowledge of Electric/Electronic Theory and Circuit Devices to Predict Changes in Current, Voltage, and Resistance in a Series Circuit

1. There would be no current if the circuit were not grounded.
2. increase
3. stay the same
4. decrease
5. Current would stop because the fuse would blow.
6. Current would increase.
7. Lower
8. Current would increase.
9. Current would decrease.
10. Without the resistor, the resistance in the circuit has decreased—therefore the current has increased. The current has increased past the circuit breaker's maximum, and the higher current is tripping the circuit breaker.
11. Resistance will increase.
12. The current in the circuit would stay at a constant level; any minor fluctuations in voltage would be eliminated by the capacitor.
13. Current would never flow in the circuit because the circuit would never be grounded—regardless of the position of the mercury switch.

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms related to circuits and circuit devices to their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. Bi-metal
2. Composite
3. Conductor
4. Contact
5. Control device
6. Diaphragm
7. Doping
8. Electrical shock
9. Electrostatic discharge
10. Filament
11. Fuse rating
12. Ground
13. Load
14. Mercury
15. Monitor
16. Pole
17. Power Source
18. Protection device
19. Resistance tolerance
20. Sensor
21. Splice
22. Throw
23. Vacuum
24. Wiper
25. Wiring diagram

____ a. Accepts the current, providing the end point necessary to maintain the flow of current through the circuit

____ b. A part that moves in response to pressure

____ c. The release of electrons to another surface

____ d. The percentage above or below its resistance value a resistor can vary and still operate correctly

____ e. The end of a switch that the wiper moves to contact

____ f. The material made of two or more different substances

____ g. To check by means of an electronic receiver

____ h. A place where two or more wires have been joined by solder or compression device

____ i. Uses the current to achieve the purpose(s) of the circuit

____ j. Provides the voltage for the current

____ k. The addition of another element or elements to a semiconductor to increase or decrease its ability to conduct current

____ m. A movable arm of a switch

____ n. Made of two dissimilar metals

____ o. The maximum amount of current a fuse will conduct without melting

____ p. Disconnects the circuit from the voltage if the current reaches a level that will damage any of the circuit elements

____ q. A space empty of matter/anything less than atmospheric pressure

____ r. Starts, stops, or in some way controls the current in the circuit

____ s. A device that converts physical quantities such as pressure, pressure differential, airflow, temperature, and velocity to produce a measurable signal

____ t. A slender wire of tungsten, carbon, or other material, which, when current flows through it in a vacuum, is heated to a brilliant glow and produces light

____ u. Provides a pathway for current to move between the circuit elements

____ v. A drawing that shows, in a simplified form, the position the circuit devices in an electrical circuit have in relation to each other

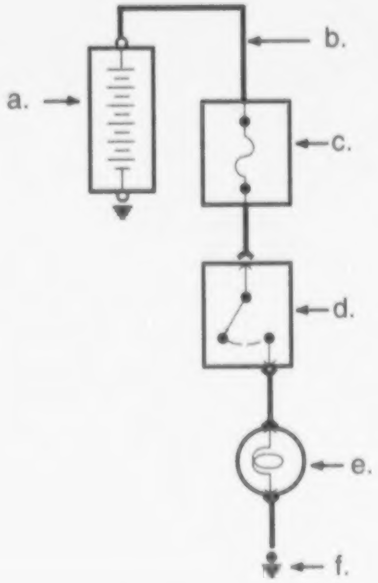
____ w. A connection between two conductors that permits a flow of current

____ x. The unbroken path through a series of connected electrical and/or electric elements where current travels from a power source to a ground

____ y. The end of a switch where the wiper is connected

Objective 2

Label the six circuit elements on an illustration of a basic vehicle circuit. Write the name of the circuit element indicated on the corresponding numbered line.



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a. ____

b. ____

c. ____

d. ____

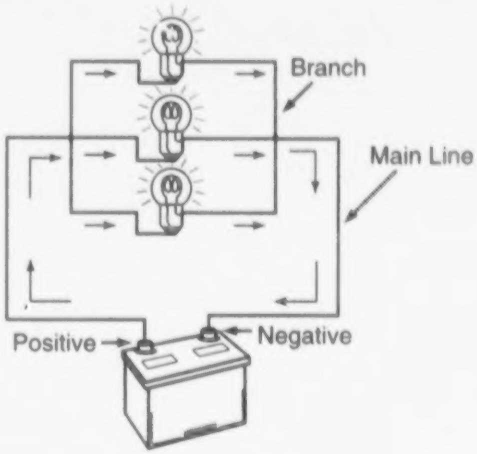
e. ____

f. ____

Written Test

Objective 3

Distinguish among four types of commonly used circuits. Write the name of the type of circuit shown on the line underneath the illustration.


Branch
Main Line
Positive
Negative

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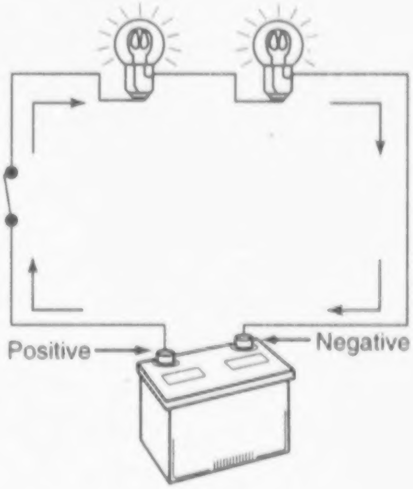
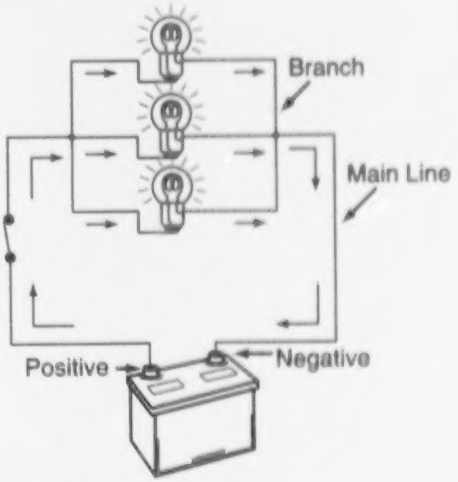
a. ______________________________


Positive
Negative

Used with permission of DaimlerChrysler Corp.

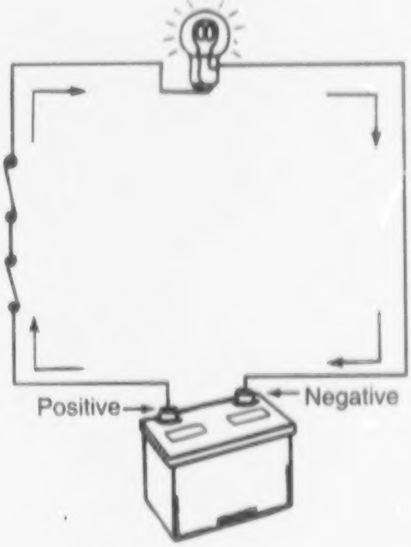
b. ______________________________

171


Branch
Main Line
Positive
Negative

Used with permission of DaimlerChrysler Corp.

c. ______________________________


Positive
Negative

d. ______________________________

Written Test

Use the following abbreviations to identify the four types of circuits. Write the abbreviation for the circuit under each statement that is true for that type of circuit. Statements may be true for more than one type of circuit.

S – series circuit
P – parallel circuit
SP – series-parallel circuit
L – logic circuit

e. One current path (called the main line) begins at the power source, divides into two or more paths (called branches) and then reunites in a single path (again called the mail iine) to the gound.

____

f. One current path begins at the power source and ends at the ground.

____

g. There is one or more load, control device, or protection device on its single path.

____

h. There is one or more load, control device, or protection device on the main line.

____

i. There is no load, control device, or protection device on the main line.

____

j. There is one or more load, control device, or protection device on each branch.

____

k. The same current flows through every circuit element.

____

l. A break anywhere on the single path stops the current to all the circuit elements.

____

m. A break in the main line stops current to all circuit elements.

____

n. A break in one branch does not stop the current through other branches or the main line.

____

o. There is one load, and two circuit or protection devices on it's single path.

____

Objective 4

List the two power sources for vehicle electrical circuits.

- ____
- ____

Objective 5

State why and where vehicle circuits are grounded.

- ____
  ____
- ____
  ____

Objective 6

Draw wiring diagram symbols that indicate a battery and a ground. Draw the symbols in the boxes. Draw the battery symbol and *one* of the ground symbols.

Battery	Ground

Written Test

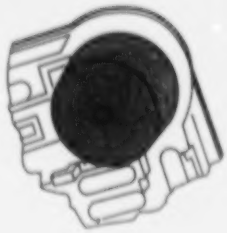
Objective 7

Distinguish among common control devices by their illustrations, wiring diagram symbols, current factor controlled, and the type of control each has on voltage or resistance in a circuit.

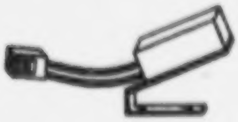
Part 1—Illustrations

Put the number of the correct illustration in the blank before the name of the control device.

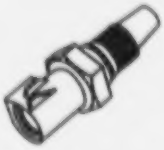
1.



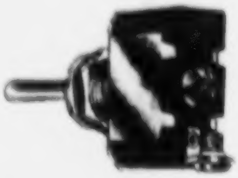
2.



3.

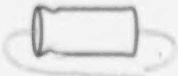


4.

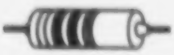


5.

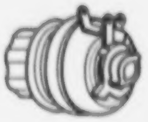
6.



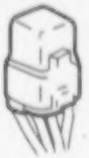
7.



8.

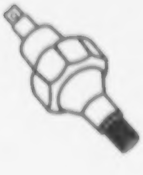


9.

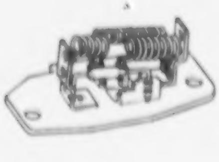


10

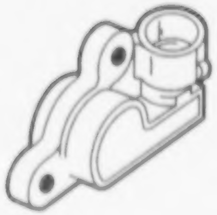
11.



12.



13.



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7 & 8 – Used with permission of DaimlerChrysler Corp.
13 – Copyright © General Motors Corp. Used with permission

____ a. capacitor

____ b. fixed resistor

____ c. flasher

____ d. mercury swtich

____ e. MPMT switch

____ f. potentiometer

____ g. pressure switch

____ h. relay

____ i. rheostate

____ j. SPDT switch

____ k. SPST switch

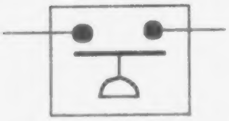
____ l. stepped resistor

____ m. temperature switch

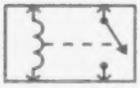
Part 2—Wiring Diagram Symbols

Put the number of the correct illustration in the blank before the name of the control device.

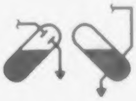
1.



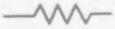
2.



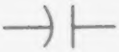
3.



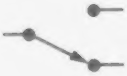
4.



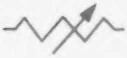
5.



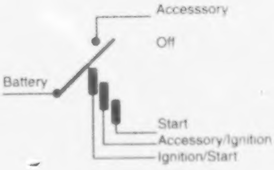
6.



7.

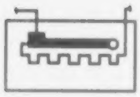


8.

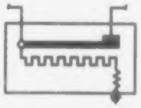

Accesssory
Off
Battery
Start
Accessory/Ignition
Ignition/Start

Written Test

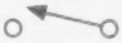
9.



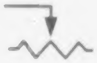
10



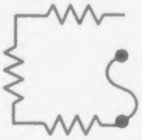
11.



12.



13.



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2, 7,11, & 12 – Used with permission of Ford Motor Co.

____ a. capacitor

____ b. fixed resistor

____ c. flasher

____ d. mercury switch

____ e. MPMT switch

____ f. potentiometer

____ g. pressure switch

____ h. relay

____ i. rheostat

____ j. SPDT switch

____ k. SPST switch

____ l. temperature switch

____ m. stepped resistor

Part 3—Current Factor Controlled

If the control device controls voltage, put **V** in the blank before the name of the device. If the control device controls resistance, put **R** in the blank.

____ a. capacitor

____ b. fixed resistor

____ c. flasher

____ d. mercury switch

____ e. MPMT switch

____ f. potentiometer

____ g. pressure switch

____ h. relay

____ i. rheostat

____ j. SPDT switch

____ k. SPST switch

____ l. stepped resistor

____ m. temperature switch

Part 4—Type of Control

Place the number of the type of control before the appropriate control device(s). Types of control may be used for more than one control device.

1. Connects and disconnects the circuit from the voltage
2. Determines which of two circuit branches is connected to the voltage
3. Determines which of several circuit branches is connected to the voltage
4. Stores and releases voltage
5. Increases resistance in the circuit
6. Increases or decreases resistance in the circuit

____ a. capacitor

____ b. fixed resistor

____ c. flasher

____ d. mercury switch

____ e. MPMT switch

____ f. potentiomenter

____ g. pressure switch

____ h. relay

____ i. rheostat

____ j. SPDT switch

____ k. SPST switch

____ l. stepped resistor

____ m. temperature switch

Written Test

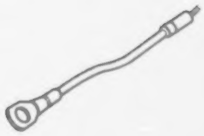
Objective 8

Distinguish among common protection devices by their illustrations and wiring diagram symbols.

Part 1—Illustrations

Put the number of the correct illustration in the blank before the name of the protection device.

1.



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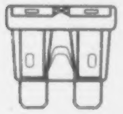
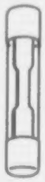
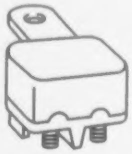
2.



3.



4.



Used with permission of DaimlerChrysler Corp.

____ a. blade fuse

____ b. circuit breaker

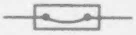
____ c. fusible link

____ d. glass fuse

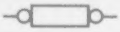
Part 2—Wiring Diagram Symbols

Put the number of the correct wiring diagram symbol in the blank before the name of the protection device. Symbols my be used for more than one protective device.

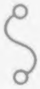
1.



2.



3.



Used with permission of Ford Motor Co.

____ a. blade fuse

____ b. circuit breaker

____ c. fusible link

____ d. glass fuse

Objective 9

List the size categories of blade fuses.

- ____________________
- ____________________
- ____________________

Objective 10

Explain how fuses, fusible links, and circuit breakers protect the circuits on which they are installed.

____

____

____

____

____

____

____

____

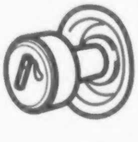
Objective 11

Distinguish among common loads by their illustrations, wiring diagram symbols, and the form of energy into which each converts current.

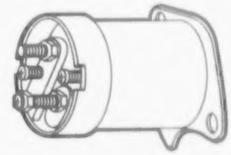
Part 1—Illustrations

Put the letter of the correct illustration in the blank before the name of load.

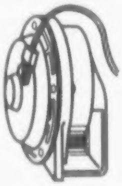
1.



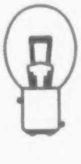
2.



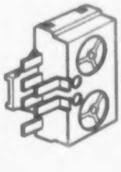
3.



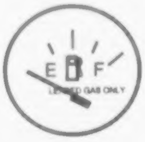
4.



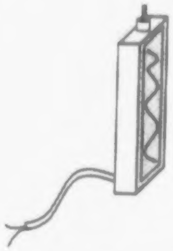
5.



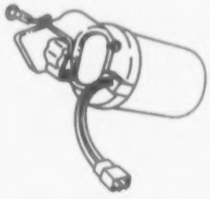
6.



7.



8.



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3, 5, 6, & 8 – Used with permission of Ford Motor Co.
2 – Copyright © General Motors Corp. Used with permission.

____ a. buzzer

____ b. cigar lighter

____ c. gauge

____ d. heated mirror grid

____ e. horn

____ f. lamp

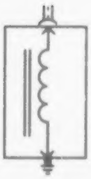
____ g. motor

____ h. solenoid

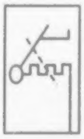
Part 2—Wiring Diagram Symbols

Put the number of the correct wiring diagram symbol in the blank before the name of the load.

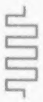
1.



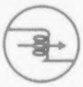
2.



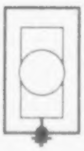
3.



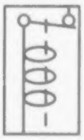
4.



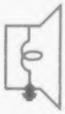
5.



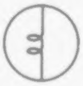
6.



7.



8.



1, 2, & 4-8 – Used with permission of Ford Motor Co.

____ a. buzzer

____ b. cigar lighter

____ c. gauge

____ d. heated mirror grid

____ e. horn

____ f. lamp

____ g. motor

____ h. solenoid

Part 3—Forms of Energy

Use the following abbreviations to identify forms of energy. Write the abbreviation for the form of energy next to the load to which it applies. Forms of energy may be used once, more than once, or not at all.

H — heat
L — light
M — motion
S — sound

____ a. buzzer

____ b. cigar lighter

____ c. gauge

____ d. heated mirror grid

____ e. horn

____ f. lamp

____ g. motor

____ h. solenoid

Written Test

Objective 12

Describe how a device that is *electronic* is different from a device that is *electric.*

Objective 13

Define the terms P-type semiconductors and N-type semiconductors.

a. P-type semiconductors — ____________________

b. N-type semiconductors — ____________________

Objective 14

List advantages and disadvantages of using electronic devices in circuits. List any five of the advantages and disadvantages.

- ____________________
- ____________________
- ____________________
- ____________________
- ____________________

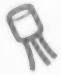
Objective 15

Distinguish among common electronic circuit devices by their illustrations, wiring diagram symbols, and functions in a circuit.

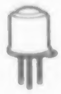
Part 1—Illustrations

Put the number of the correct illustration in the blank before the name of the electronic circuit device.

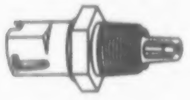
1.



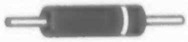
2.



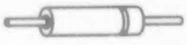
3.



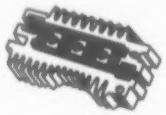
4.



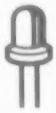
5.



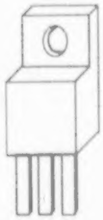
6.



7.



8.



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____ a. diode

____ b. diode rectifier bridge

____ c. light-emitting diode (LED)

____ d. phototransistor

____ e. thermistor

____ f. transistor

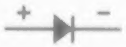
____ g. zener diode

____ h. thyristor

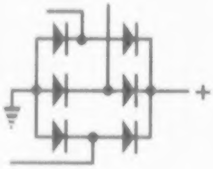
Part 2—Wiring Diagram Symbols

Put the number of the correct wiring diagram symbol in the blank before the name of the electronic circuit device.

1.



2.



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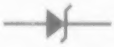
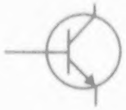
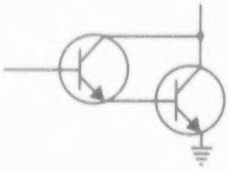


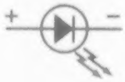
4.



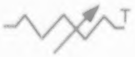
5.



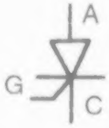
6.



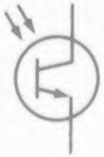
7.



8.



9.



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7 – Used with permission of Ford Motor Co.

____ a. Darlington pair

____ b. diode

____ c. diode rectifier bridge

____ d. light-emitting diode (LED)

____ e. phototransistor

____ f. thermistor

____ g. transistor

____ h. zener diode

____ i. thyristor

Part 3—Functions in a Circuit

Use the following abbreviations to identify the functions of the electronic circuit devices. Place the correct abbreviations in the blank. (Abbreviations may be used once, more than once, or not at all.)

C — conductor
CD — control device
G — ground
L — load
PD — protection device
PS — power source

____ a. Darlington pair

____ b. diode

____ c. diode rectifier bridge

____ d. light-emitting diode (LED)

____ e. phototransistor

____ f. thermistor

____ g. transistor

____ h. zener diode

____ i. thyristor

Written Test

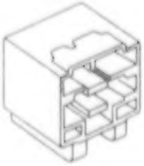
Objective 16

Distinguish among common conductors by their illustrations and wiring diagram symbols.

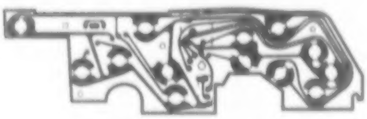
Part 1—Illustrations

Put the number of the correct illustration in the blank before the name of the conductor.

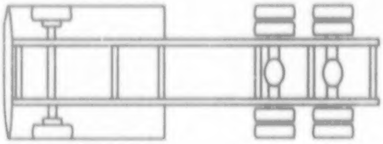
1.



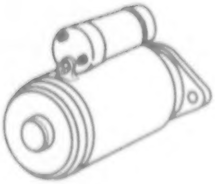
2.



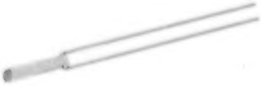
3.



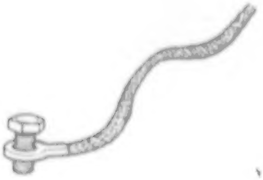
4.



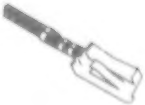
5.



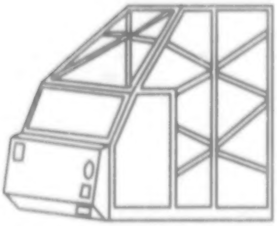
6.



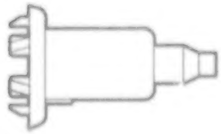
7.



8.



9.



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____ a. component case

____ b. connector

____ c. ground strap/wire

____ d. printed circuit board

____ e. socket

____ f. terminal

____ g. vehicle body

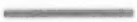
____ h. vehicle frame

____ i. wire

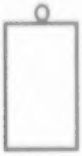
Part 2—Wiring Diagram Symbols

Put the number of the correct wiring diagram symbol in the blank before the name of the conductor.

1.



2.



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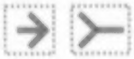
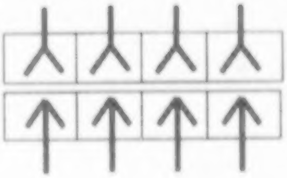
3.



4.



____ a. component case

____ b. connector

____ c. terminal

____ d. wire

Objective 17

Name four types of material that are commonly used as insulators in vehicle electrical systems.

- ______________________________
- ______________________________
- ______________________________
- ______________________________

Objective 18

Explain the purpose of a wire shield.

____

____

____

____

Written Test

Objective 19

Part 1

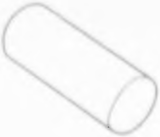
List three purposes of wiring hardware.

- ______________________________
- ______________________________
- ______________________________

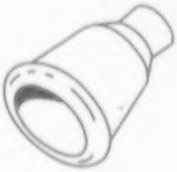
Part 2

Match the names of wiring hardware to illustrations of the hardware. Put the letter of the correct illustration in the blank before the name of the wiring hardware.

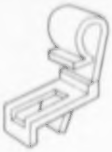
1.



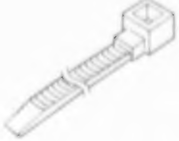
2.



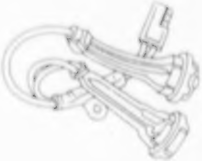
3.



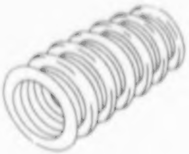
4.



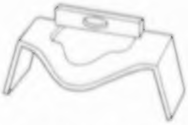
5.



6.



7.



1-7 – Used with permission of DaimlerChrysler Corp

____ a. boot

____ b. clip

____ c. retainer

____ d. sleeve

____ e. tubing

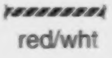
____ f. tie strap

____ g. wiring harness

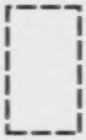
Objective 20

Match the names of common circuit features to the wiring diagram symbols that represent the features. Put the number of the correct wiring diagram symbol in the blank before the name of the circuit feature it represents.

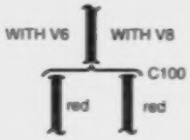
1.



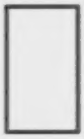
2.



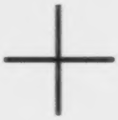
3.



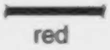
4.



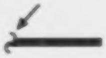
5.



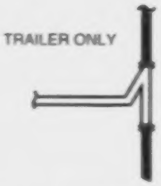
6.



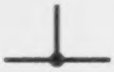
7.



8.



9.



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5 & 9 – Used with permission of DaimlerChrysler Corp.

____ a. alternate circuit path

____ b. wire continues somewhere else

____ c. component shown in two places

____ d. optional wiring

____ e. sealed or solid state component

____ f. solid colored wire

____ g. splice

____ h. striped wire

____ i. wires crossed, not connected

Objective 21

Distinguish among types of wiring diagrams by placing the abbreviation for the type of wiring diagram under each statement that is true for that type of diagram. Abbreviations may be used more than once.

SL — Single line diagram
H — Harness diagram
L — Ladder diagram
R — Routing diagram

____ a. Used for most troubleshooting procedures

____ b. Shows where each wire "breaks out" of the harness and where it connects into a terminal

____ c. Shows connector locations on vehicle

____ d. Numbers on the harness body indicate how long that particular run of harness is

____ e. Diagram may be several pages long with circuit devices on different pages

____ f. Shows grounding points on vehicle

____ g. Allows tracing of each individual circuit

____ h. Each horizontal rung is an individual basic circuit

____ i. Shows connector and terminal manufacturers as well as their part numbers

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 12
b. 6
c. 9
d. 19
e. 22
f. 2
g. 15
h. 21
i. 13
j. 17
k. 7
l. 14
m. 24
n. 1
o. 11
p. 18
q. 23
r. 5
s. 20
t. 10
u. 3
v. 25
w. 4
x. 8
y. 16

Objective 2

a. power source
b. conductor
c. protection device
d. control device
e. load
f. ground

Objective 3

a. parallel circuit
b. series-parallel circuit
c. series circuit
d. logic circuit
e. P, SP
f. S, L
g. S
h. P, SP
i. P
j. P, SP
k. S, L
l. S, L
m. P, SP
n. P, SP
o. L

Objective 4

The answer should include both of the following, in any order:

- battery
- alternator/generator

Answers to Written Test

Objective 5

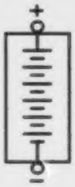
The answer should include both of the following, in any order:

- Most automotive circuits are grounded to the negative terminal of the battery.
- If a circuit is not grounded, current will not flow through it.

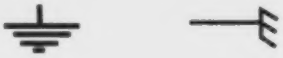
Objective 6

The answer should include both of the following symbols for a battery and *either* of the symbols for a ground.

Battery



Ground



Objective 7

Part 1

a.	6	f.	13	k.	4
b.	7	g.	11	l.	12
c.	1	h.	9	m.	3
d.	2	i.	8		
e.	10	j.	5		

Part 2

a.	5	f.	12	k.	11
b.	4	g.	1	l.	10
c.	9	h.	2	m.	13
d.	3	i.	7		
e.	8	j.	6		

Part 3

a.	V	f.	R	k.	V
b.	R	g.	V	l.	R
c.	V	h.	V	m.	V
d.	V	i.	R		
e.	V	j.	V		

Part 4

a.	4	f.	6	k.	1
b.	5	g.	1	l.	6
c.	1	h.	1	m.	1
d.	1	i.	6		
e.	3	j.	2		

Objective 8

Part 1
a. 2
b. 4
c. 1
d. 3

Part 2
a. 3
b. 1
c. 2
d. 3

Objective 9

The answer should include all of the following, in any order:

- autofuse or standard fuse
- maxifuse
- minifuse

Objective 10

Every fuse, fusible link, and circuit breaker is designed to conduct only a predetermined amount of current. When too much current flows through them, they melt (or in the case of a circuit breaker, warp), disconnecting the circuit from the voltage before other circuit devices on the circuit can be damaged.

Objective 11

Part 1
a. 5
b. 1
c. 6
d. 7
e. 3
f. 4
g. 8
h. 2

Part 2
a. 6
b. 2
c. 4
d. 3
e. 7
f. 8
g. 5
h. 1

Part 3
a. S
b. H
c. M
d. H
e. S
f. L
g. M
h. M

Objective 12

If current flows through a conductor in the device, the device is *electric*. If current flows through a vacuum, a gas, or a semiconductor in the device, the device is *electronic*.

Answers to Written Test

Objective 13

a. (P-type semiconductor) A doped semiconductor that acts as though it has a positive charge—it attracts electrons.

b. (N-type semiconductor) A doped semiconductor that acts as though it has a negative charge—it loses electrons.

Objective 14

The answer should include five of the following, in any order:

- more reliable
- require no maintenance
- lighter
- cheaper
- operate using lower voltage
- smaller
- function easily with computers
- can be easily damaged by too much current or by electrostatic discharge
- are easily influenced by the magnetic field surrounding nearby conductors

Objective 15

Part 1

a. 5
b. 6
c. 7
d. 2
e. 3
f. 1
g. 4
h. 8

Part 2

a. 5
b. 1
c. 2
d. 6
e. 9
f. 7
g. 4
h. 3
i. 8

Part 3

a. CD
b. CD
c. CD
d. L
e. CD
f. CD
g. CD
h. CD
i. CD

Objective 16

Part 1

a. 4
b. 1
c. 6
d. 2
e. 9
f. 7
g. 8
h. 3
i. 5

Part 2

a. 2
b. 4
c. 3
d. 1

Objective 17

The answer should include all of the following, in any order:

- rubber
- plastic
- porcelain
- cheaper
- paper

Objective 18

A wire shield protects a wire from the influence of the electromagnetic energy which surrounds nearby electrical circuits so the energy does not interfere with the operation of circuits serving electronic components or components to radio or sound equipment.

Objective 19

Part 1

The answer should include all of the following, in any order:

- Support the electrical wiring
- Keep the wiring in the correct position
- Protect the wiring from being damaged

Part 2

a. 2
b. 3
c. 7
d. 1
e. 6
f. 4
g. 5

Answers to Written Test

Objective 20

a. 3
b. 7
c. 2
d. 8
e. 4
f. 6
g. 9
h. 1
i. 5

Objective 21

a. SL
b. H
c. R
d. H
e. L
f. R
g. SL
h. L
i. H

Unit 2 Understanding Circuits & Circuit Devices

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 7, and Student Supplement 1.

☐ 4. **Do** Assignment Sheet 1, "Explain What the Color Bands Found on Resistors Represent, and Use the Color Bands on a Resistor to Determine its Resistance Value."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 8 through 10.

☐ 7. **Do** Assignment Sheet 2, "Determine Correct Replacement Fuses."

☐ 8. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat Steps 6 and 7.

☐ 9. **Study** Information Sheet, Objective 11 and Student Supplement 2, "Motors".

☐ 10. **Study** Information Sheet, Objectives 12 through 15, Student Supplement 3, "Diodes", and Student Supplement 4, "Electrical Wire".

☐ 11. **Study** Information Sheet, Objectives 16 through 21, and Student Supplement 5, "Electrical Wire".

Learning Activities Sheet

☐ 12. **Do** Assignment Sheet 3, "Use Wire Color and Circuit Identification Codes to Locate Circuit Information".

☐ 13. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, repeat Steps 11 and 12.

☐ 14. **Do** Assignment Sheet 4, "Using Wiring Diagrams to Locate Information About Circuits".

☐ 15. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, repeat Steps 13 and 14.

☐ 16. **Do** Assignment Sheet 5, "Use Your Knowledge of Electric/Electronic Theory to Predict Changes in Current, Voltage, and Resistance in a Series Circuit".

☐ 17. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, repeat Steps 15 and 16.

☐ 18. **Do** Job Sheet 1, "Inspect, Test, and Replace Spike Suppression Diodes/Resistors".

☐ 19. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 20. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 18.

☐ 20. **Check** With instructor for any additional assignments to be completed.

☐ 21. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 22. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

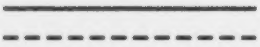
***Permission to duplicate this form is granted.**

Teacher Supplement 1—Wiring Diagram Symbols

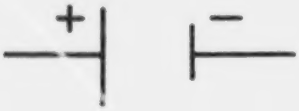
In order to read vehicle wiring diagrams of any kind, it is critical that students be familiar with the various wiring diagram symbols used in the diesel industry. Although these symbols are not standardized throughout the industry, below you'll find some of the most commonly used symbols.

a. **Current**

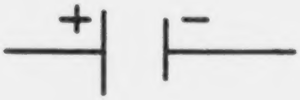
1. Direct current



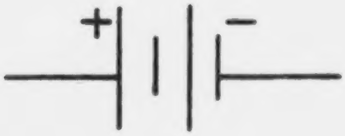
2. Generalized direct current source



3. One cell

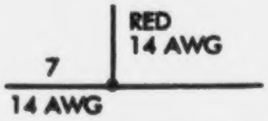


4. Multicell

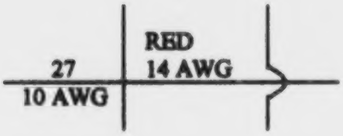


b. Conductors (wiring)

1. Connected (junction)



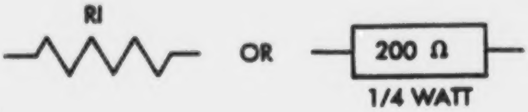
2. Crossing of conductors not connected



Note: Wiring should be identified with a numeric code or a color code and the wire gauge (size) adjacent to the wire.

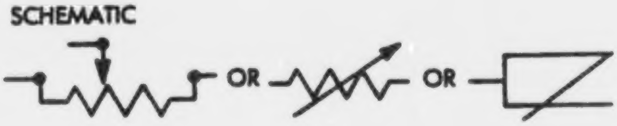
c. **Resistor**

1. Fixed value



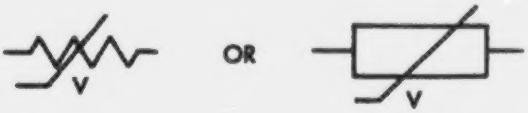
Note: Identification or value and rating within or adjacent to resistor.

2. Adjustable



Adjustable or continuously adjustable resistor, rheostat or potentiometer. See previous note and symbol k-8.

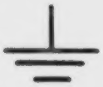
3. Varistor & voltage-sensitive resistor



Note: A varistor (See also Diode h-1) can be used in EEC power supply circuits to eliminate or reduce to an acceptable level, transient voltage spikes caused by the collapse of a magnetic field in a coil when the coil is de-energized.

d. **Circuit return**

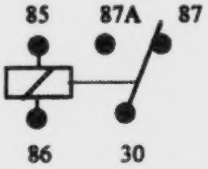
1. Ground



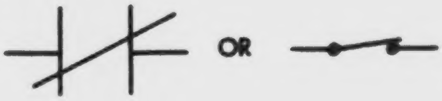
Note: A conducting connection to a structure that serves a function similar to that of an earth ground (that is, a structure, such as a frame of a vehicle or the vehicle battery that is not conductively connected to earth).

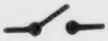
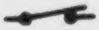
e. **Relays**

The standard method of showing contacts is by a symbol indicating the circuit condition it produces when the actuating device is in the de-energized or non-operating position. The actuating device may be mechanical, electrical, or other nature and a clarifying note may be added to explain the contact's function; for example, the point were contact closes or opens as a function of changing pressure, temperature, level, flow, voltage, current, etc.

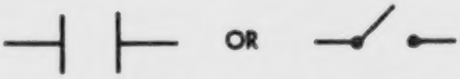


1. Closed contact

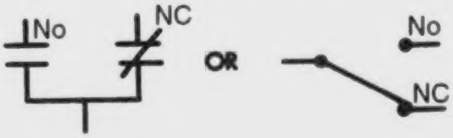


Note: Alternative style of contact  or  is also used for single pole single throw (SPST) switch (See f-1). A clarifying note may be added to prevent confusion.

2. Open contact



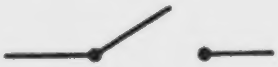
3. Transfer



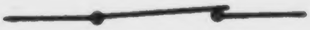
f. **Switches**

1. Single-pole single throw switch (SPST)

- Normally open

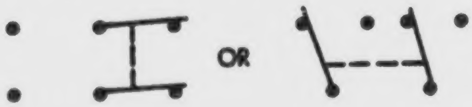


- Normally closed

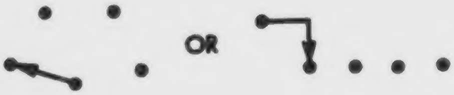


See Note e-1.

2. Double-pole double throw switch (DPDT)

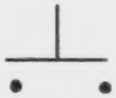


3. Multi-position switch

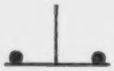


4. Push button momentary or spring return

   - Circuit closing (make)

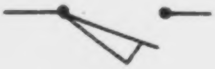


   - Circuit opening (break)

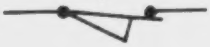


5. Limit switch. Directly actuated, spring return (micro switch)

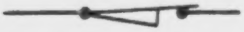
   - Normal open



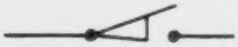
   - Normally open—held closed



   - Normally closed

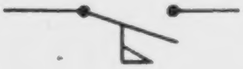


   - Normally closed—held open

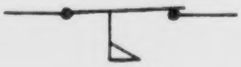


6. Flow actuated switch

   - Closes on increase in flow

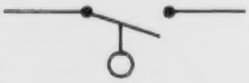


- Open on increase in flow

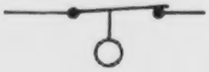


7. Liquid level actuated switch

- Closes on rising level

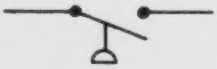


- Opens on rising level

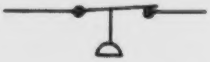


8. Pressure or vacuum actuated switch

- Closes on rising pressure

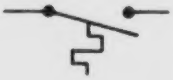


- Opens on rising level

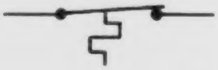


9. Temperature actuated switch

- Closes on rising temperature



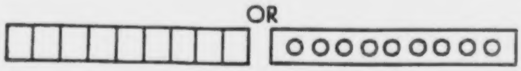
- Opens on rising temperature



205

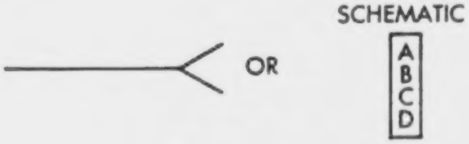
g. **Terminals and connectors**

1. Terminal board or terminal strip

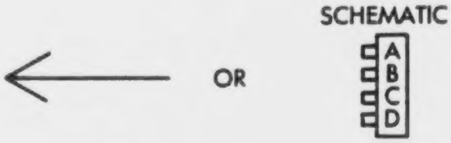


2. Connector or disconnecting device

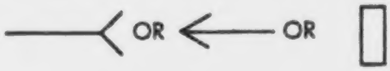
- Female terminal


OR
SCHEMATIC
A
B
C
D

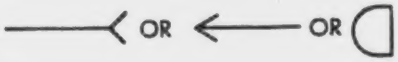
- Male terminal


OR
SCHEMATIC
A
B
C
D

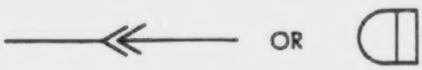
3. Receptacle (usually stationary)



4. Plug (usually movable)

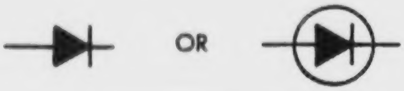


5. Separate connectors (engaged)



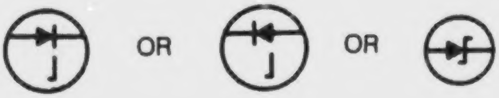
h. **Semiconductors**

1. Diode

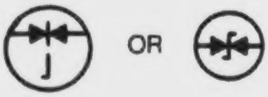


See Note c-3 on varistor use in EEC power supply circuits.

- Undirectional diode; voltage regulator

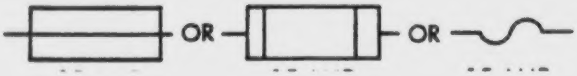


- Bidirectional diode

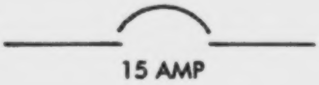


i. **Circuit protectors**

1. Fuse



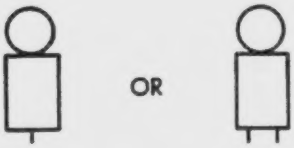
2. Circuit breaker



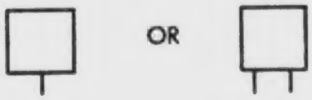
Note: Fuse capacity (value) adjacent to protective device.

j. **Audible and visual signalling devices**

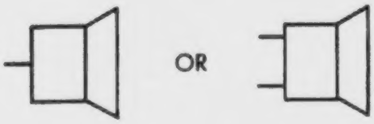
1. Bell



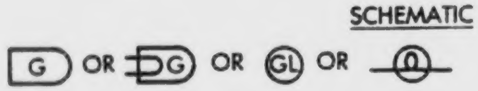
2. Buzzer



3. Horn or siren



4. Indicator or signalling light



Applications shown: green light

Note: The characteristics of the light may be shown within or adjacent to the symbol. See j-5.

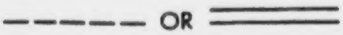
- Light characteristics

A	Amber	P	Purple
B	Blue	R	Red
C	Clear	W	White
G	Green	Y	Yellow
O	Orange		
OP	Opalescent		
Arc	Arc		
EL	Eletroluminescent		
FL	Flourescent		
MG	Mercury vapour		
NE	Neon		
UV	Ultra violet		
XE	Xenon		
LED	Light Emitting Diode		

k. **Mechanical connection, motion & rotation**

The preferred location of the mechanical connection is as shown in the various applications. For example, see f-4 double pole double throw switch.

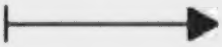
1. Mechanical connection



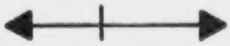
Note: The short parallel lines wil only be used when there is insufficient space for the short dashes.

2. Mechanical motion

- One direction

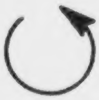


- Both directions

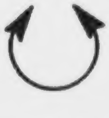


3. Mechanical rotation

- One direction

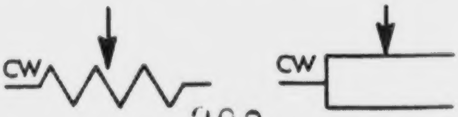


- Both directions

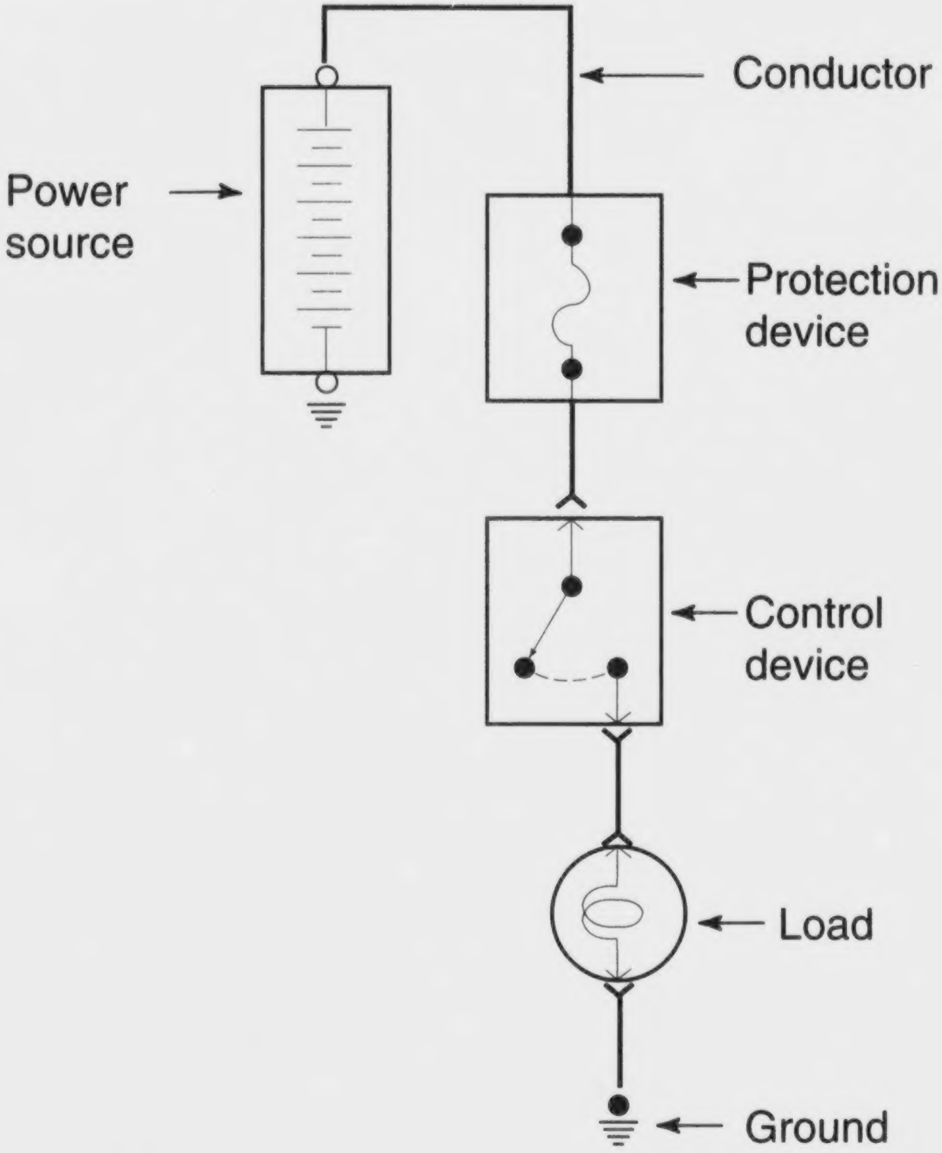


4. Rotation designation (applied to a resistor)

CW indicates position of adjustable contact at the limit of clockwise travel viewed form knob or actuator end unless otherwise indicated.



Basic Vehicle Circuit


Conductor
Power source
Protection device
Control device
Load
Ground

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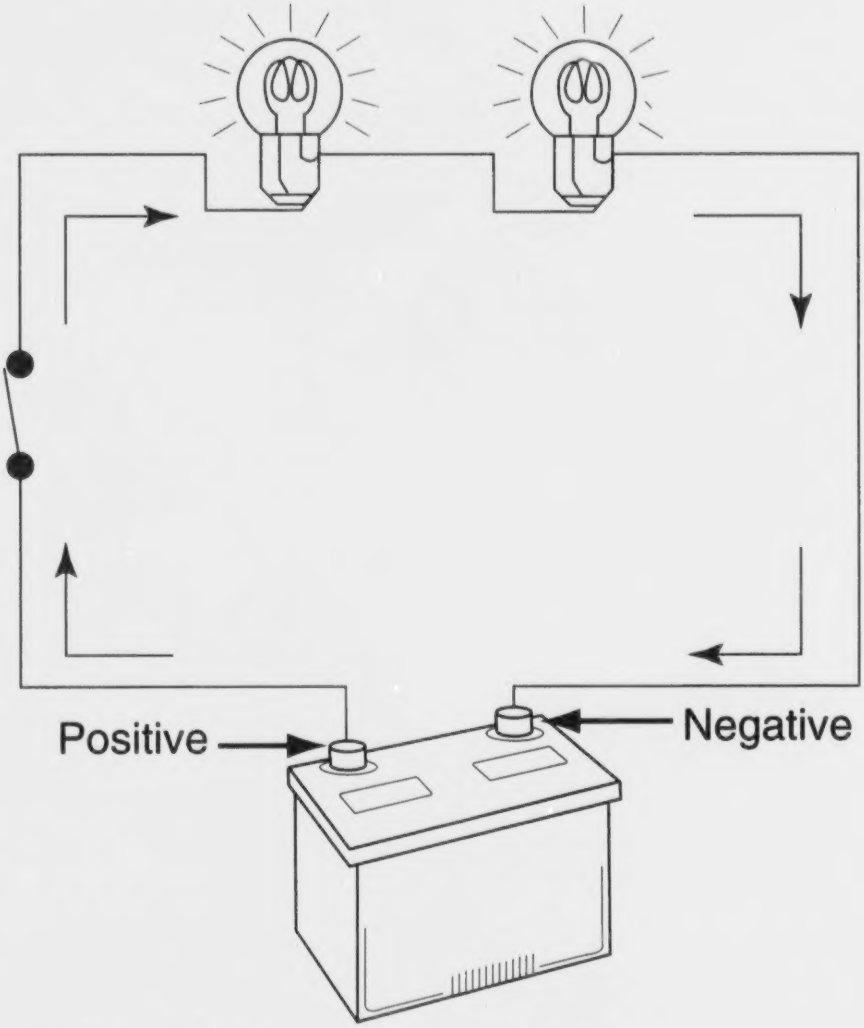
Series Circuit


Positive
Negative

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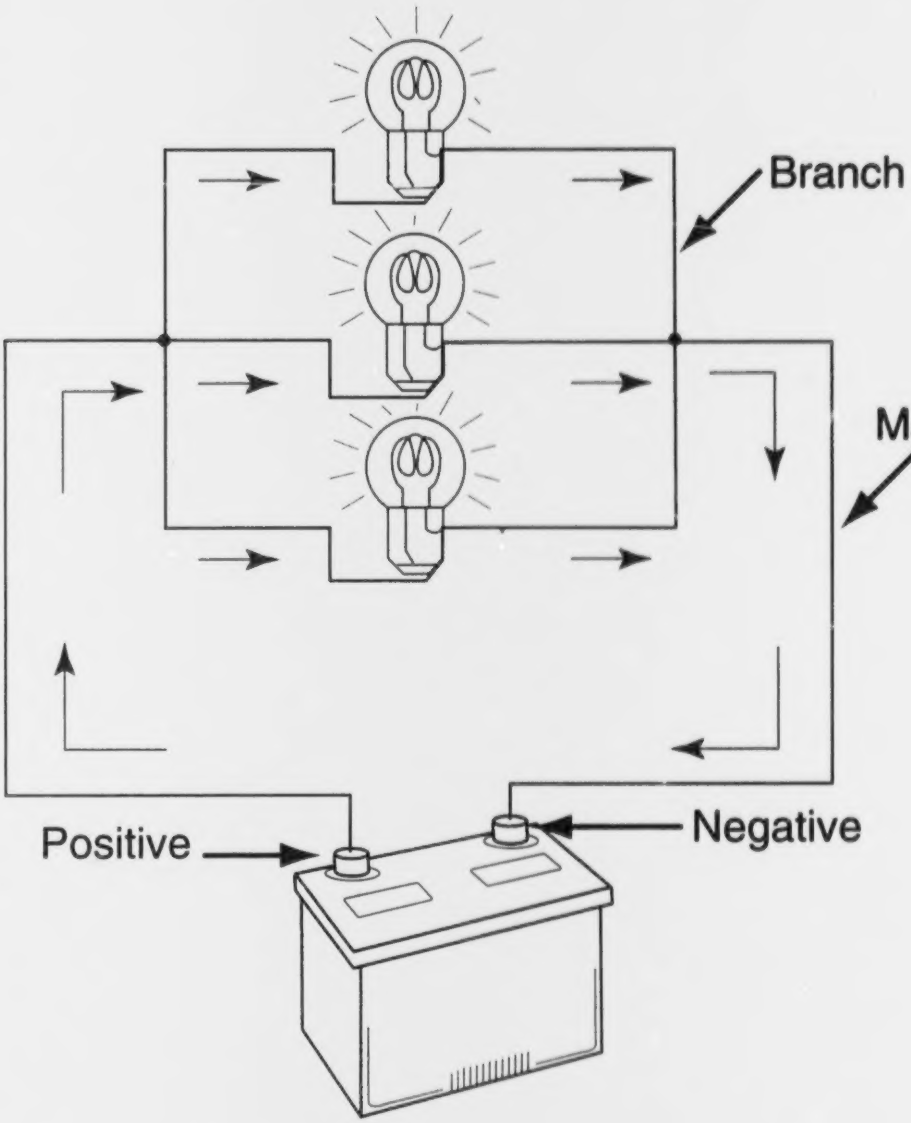
Parallel Circuit


Branch
Main Line
Positive
Negative

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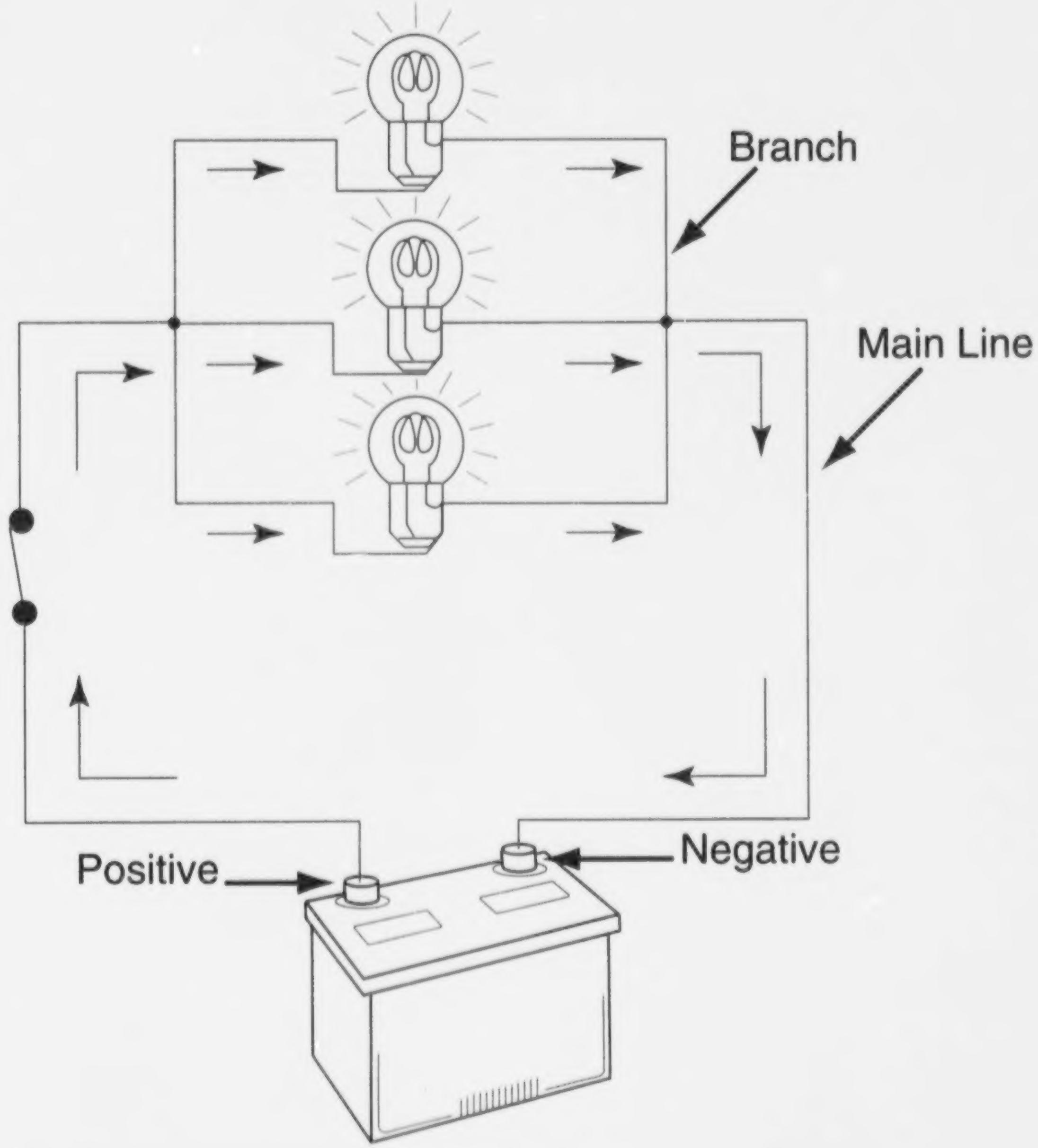
Series-Parallel Circuit


Branch
Main Line
Positive
Negative

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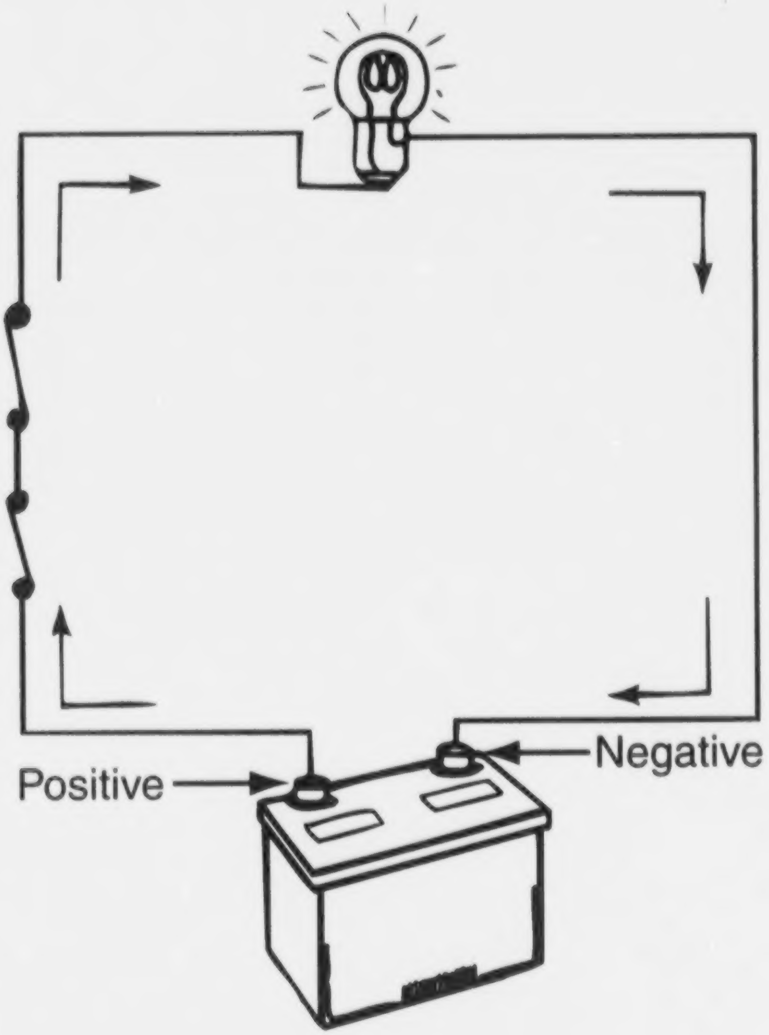
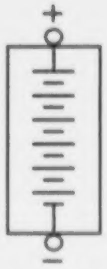
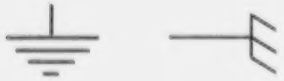
Logic Circuit


Positive
Negative

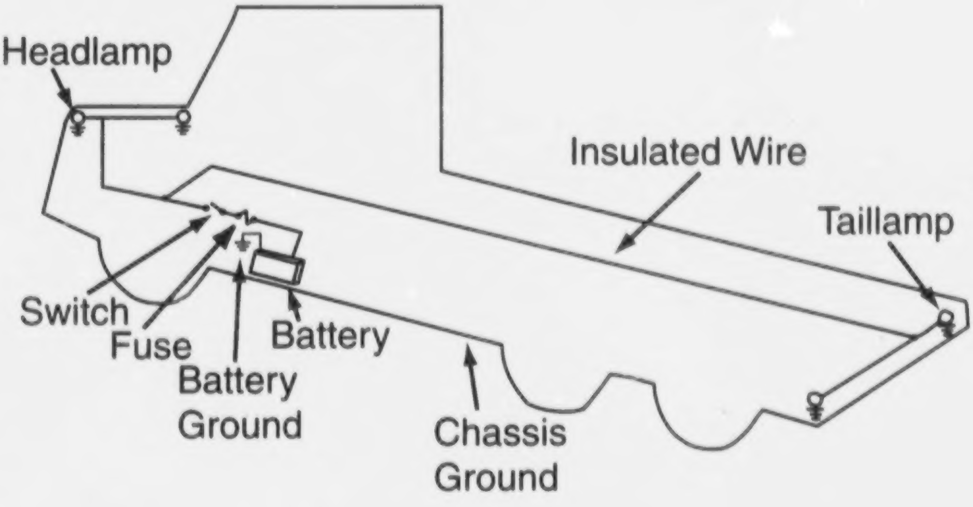
Battery Symbol



Ground Symbols

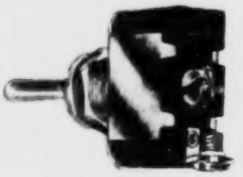


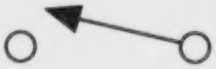
Vehicle Ground System


Headlamp
Insulated Wire
Taillamp
Switch
Fuse
Battery
Battery Ground
Chassis Ground

TM 6

SPST Switch (single pole, single throw)





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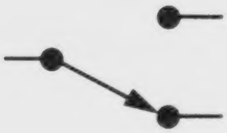
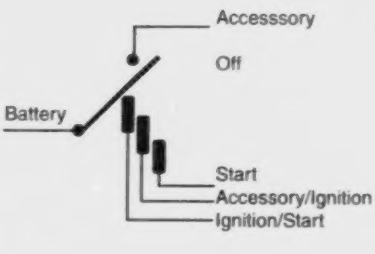
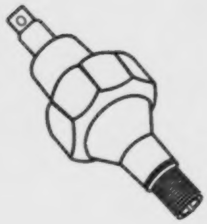
SPDT Switch (single pole, double throw)

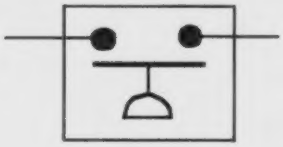


MPMT Switch multiple pole, multiple throw

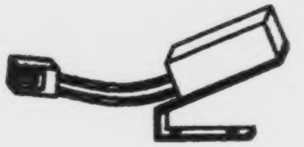

Accesssory
Off
Battery
Start
Accessory/Ignition
Ignition/Start

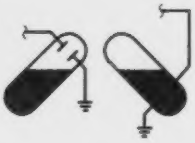
Pressure Switch





Mercury Switch





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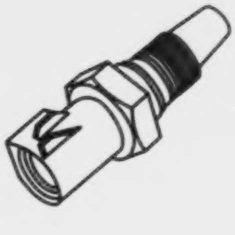
Temperature Switch



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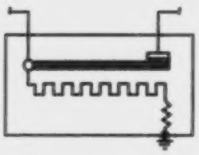

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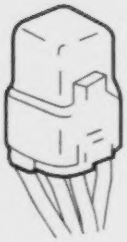
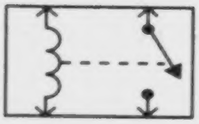
TM 8

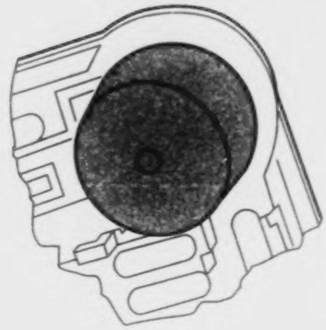
Relay

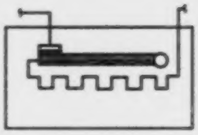




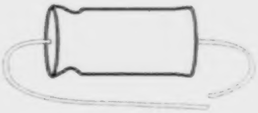
Used with permission of Ford Motor Co.

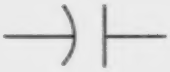
Flasher





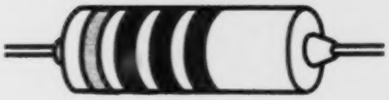
Capacitor

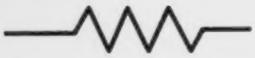




TM 9

Fixed Resistor





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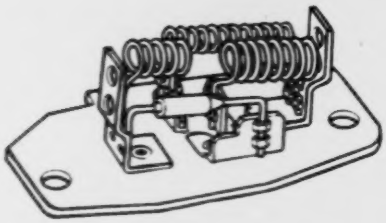
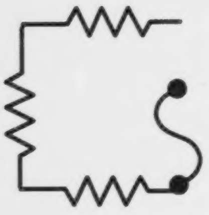
Stepped Resistor





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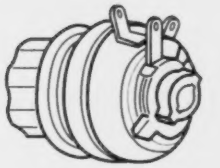
Rheostat



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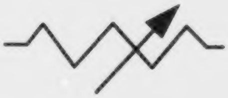

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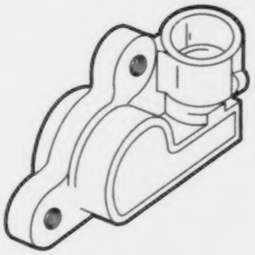
Potentiometer



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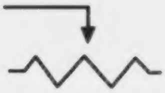

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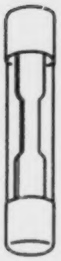
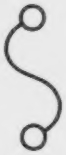
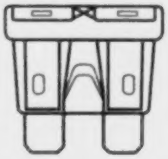
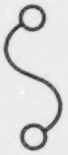
Glass Fuse





Blade Fuse





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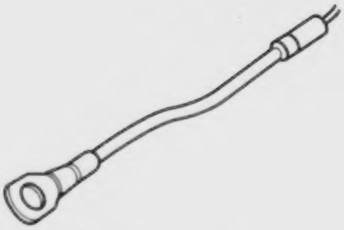
Fusible Link



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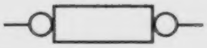

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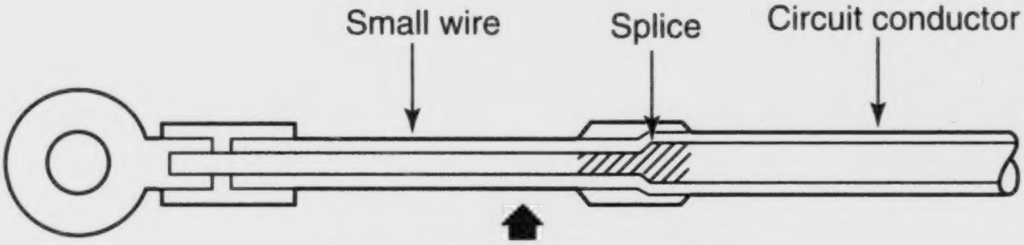
Fusible Link Operation


Small wire
Splice
Circuit conductor

Fuse link will burn out in this area when too much current flows through.

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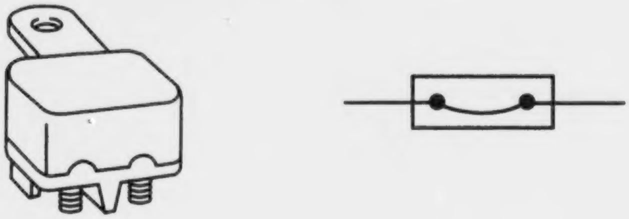
Circuit Breaker



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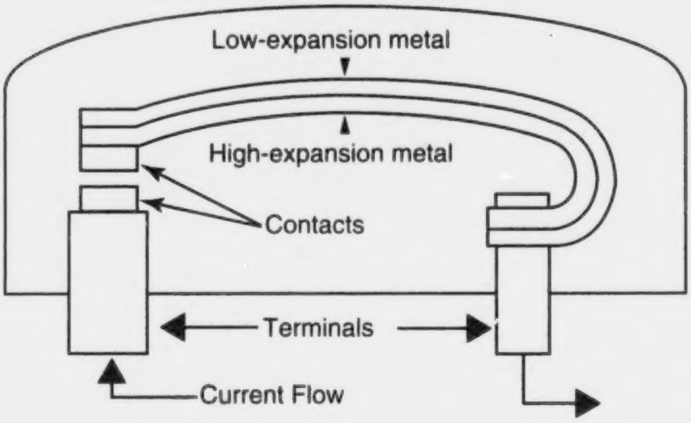
Circuit Breaker Operation


Low-expansion metal
High-expansion metal
Contacts
Terminals
Current Flow

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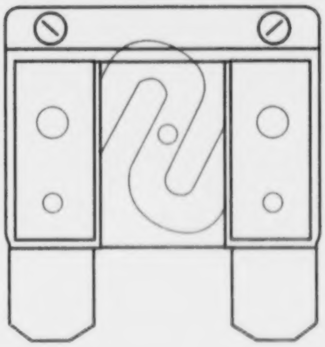
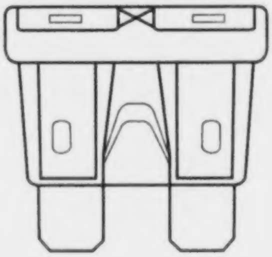
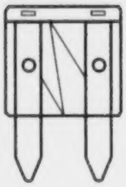
Six Categories of Blade Fuses



Maxifuse

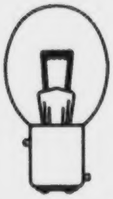


Autofuse



Minifuse

Lamp



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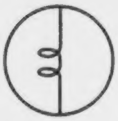

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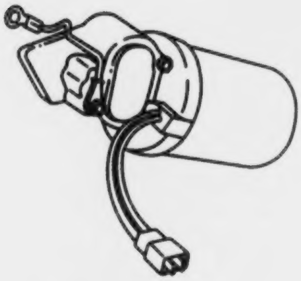
Motor



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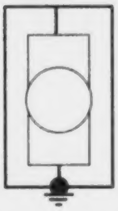

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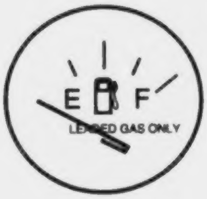
Gauge



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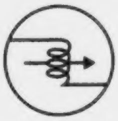

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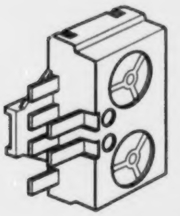
Buzzer



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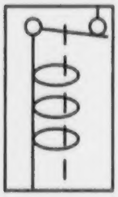

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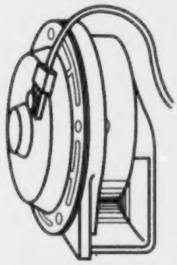
Horn



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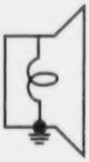

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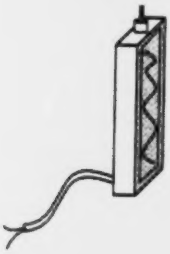
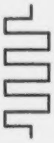
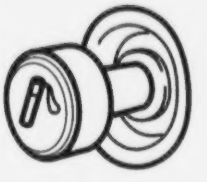
Heated Mirror Grid





Cigar Lighter



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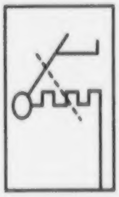

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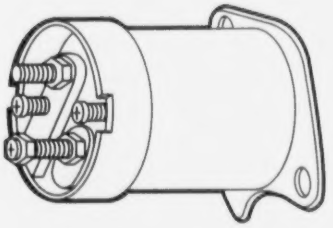
Solenoid



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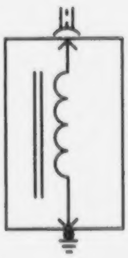

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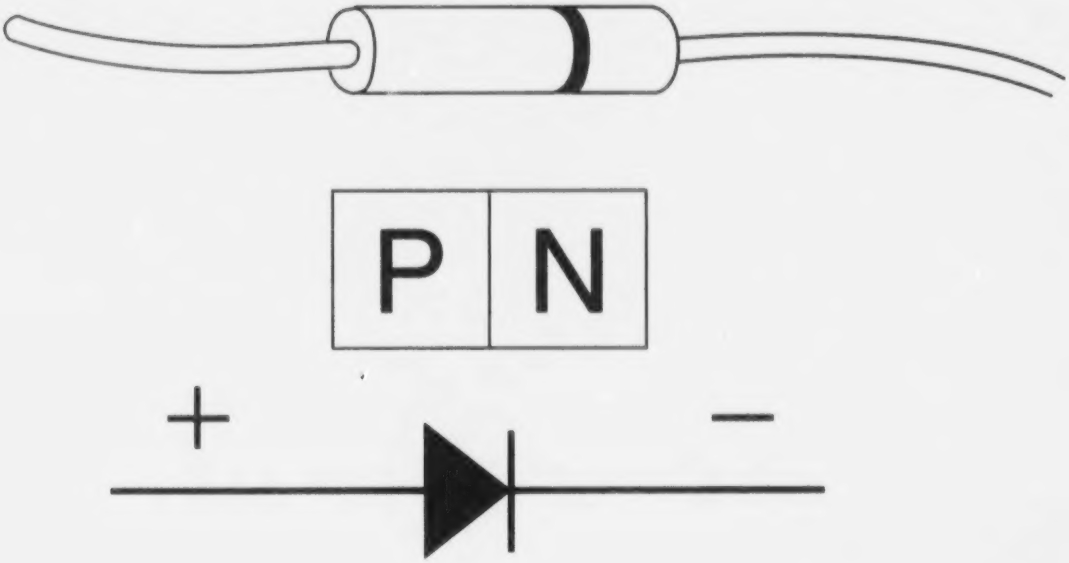
TM 18

Simple Semiconductor



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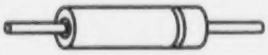
Diode



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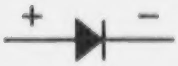

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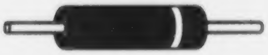
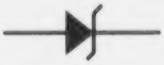
Zener Diode





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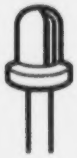
Light-Emitting Diode (LED)



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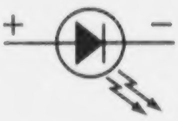

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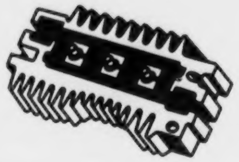
Diode Rectifier Bridge



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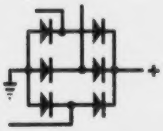

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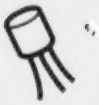
Transistor



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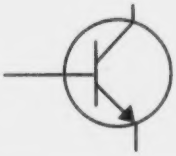

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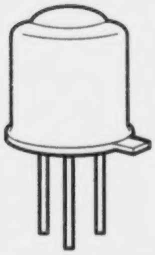
Phototransistor



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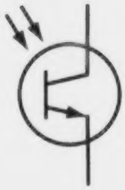

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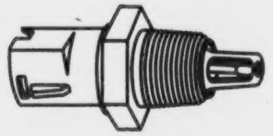
TM 21

Thermistor



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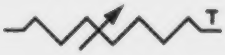

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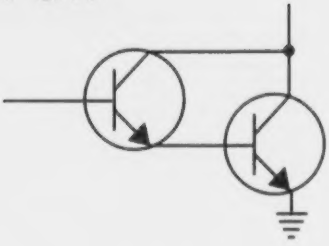
Darlington Pair

(found only on circuit boards)



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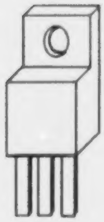
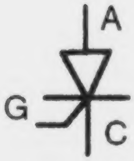
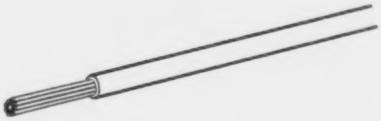
Thyristor





Wire



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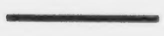
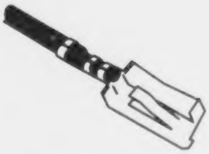


Terminal



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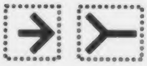
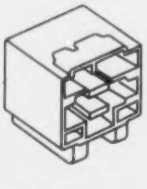


Connector



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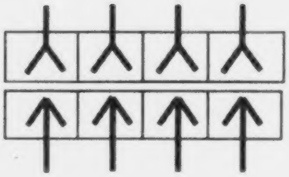
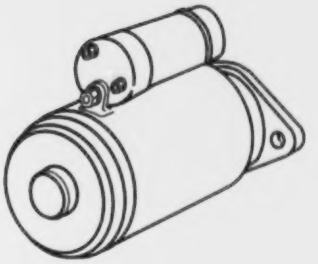


Component Case



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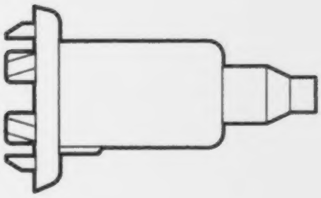
Socket



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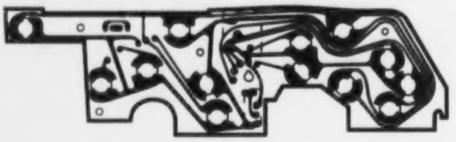
Printed Circuit Board



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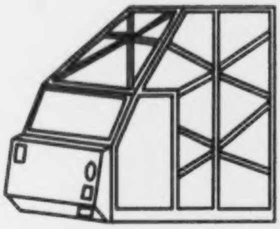
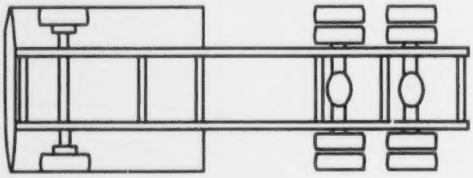
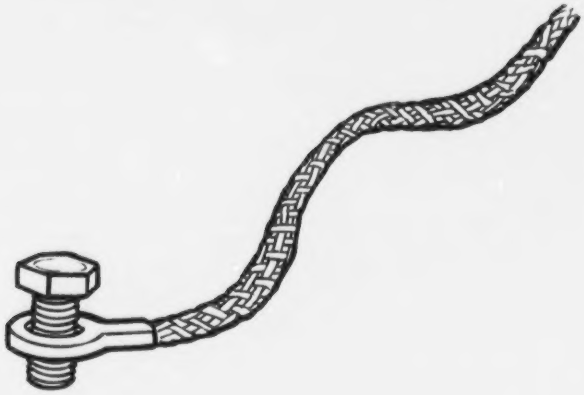
Vehicle Body



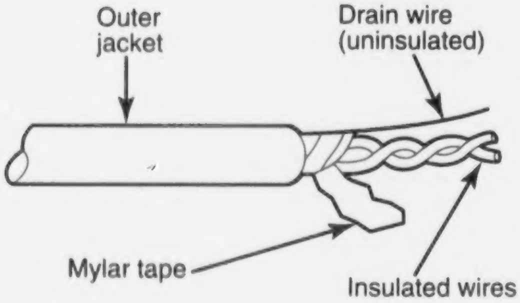
Vehicle Frame



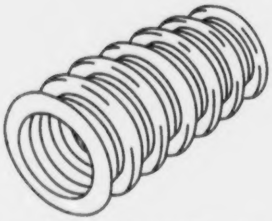
Ground Strap



Wire Shield


Outer jacket
Drain wire (uninsulated)
Mylar tape
Insulated wires

Tubing



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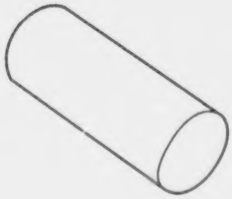
Sleeve



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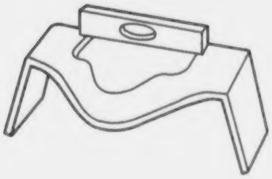
Retainer



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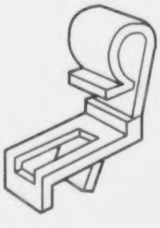
Clip



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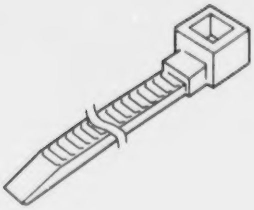
Tie Strap



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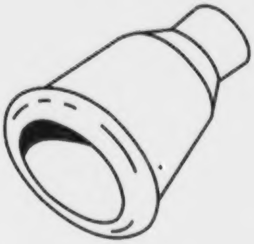
Boot



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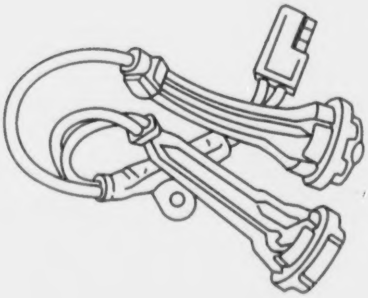
Wiring Harness



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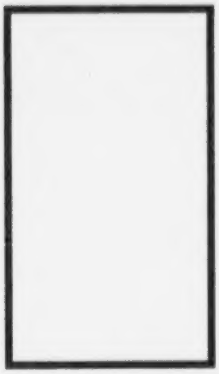
Sealed or Solid State Component



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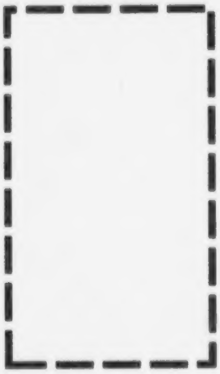
Component Shown in 2 Places



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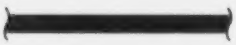
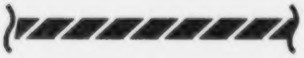
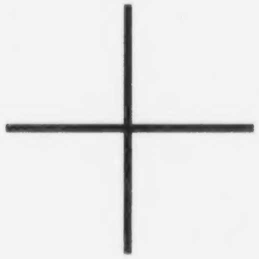
Solid Colored Wire



Striped Wire



Wires Crossed, Not Connected



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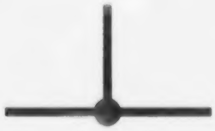
Splice



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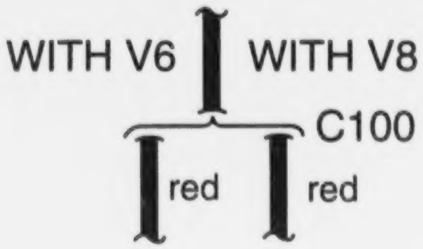
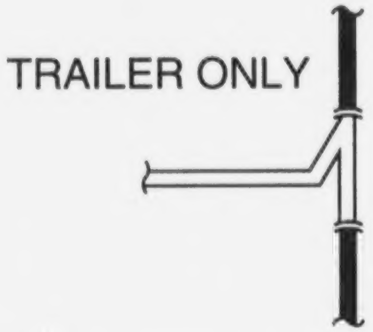
Alternate Circuit Paths


WITH V6
WITH V8
C100
red
red

Optional Wiring


TRAILER ONLY

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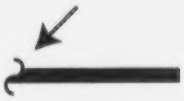
Wire Continues Somewhere Else



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Unit 3 Developing Basic Diagnosis & Repair Skills

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1 — Open Circuit—Wiring Diagram Symbol (Objective 3)
TM 2 — Open Circuit—Causes (Objective 3)
TM 3 — Short to Ground (Objective 3)
TM 4 — Wire-to-Wire (Objective 3)
TM 5 — Short to Voltage (Objective 3)
TM 6 — Typical Short Circuits (Objective 3)
TM 7 — High Resistance Problems Icon (Objective 3)
TM 8 — Typical High Resistance Problems (Objective 3)
TM 9 — Jumper Wires (Objective 4)
TM 10 — Digital Multimeter (Objective 4)
TM 11 — Scan Tools (Objective 4)
TM 12 — 12-Volt Test Light (Objective 4)
TM 13 — Self-Powered Test Light (Objective 4)
TM 14 — Logic Probe (Objective 4)
TM 15 — Vehicle Interface Module (Objective 4)
TM 16 — Harness Pinout/Breakout Box (Objective 4)
TM 17 — Spliced Wires (Objective 6)
TM 18 — Open-Barrel Crimping (Student Supplement 3)
TM 19 — Wire Connectors (Student Supplement 3)
TM 20 — Wire Connectors—Continued (Student Supplement 3)

Suggested Activities

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Invite an electrical specialist from a local diesel equipment shop to talk about common repair work required on electrical systems, as well as the increasing use of electronics on diesel equipment.
- Set up samples of series, parallel, and series-parallel circuits to demonstrate the differences between them.
- Show examples of opens, shorts to ground and voltage, and high resistance, and demonstrate how each affects vehicle operation.
- Show electrical diagnostic instruments used to measure electrical characteristics. Also demonstrate how these should be used and how their readings will be used to diagnose electrical problems.
- Demonstrate each step in electrical troubleshooting using an actual electrical problem on a vehicle.
- Divide students into groups of two and have one act as the customer and the other as an electrical technician. Develop a script and have students use it to practice their listening skills as the customer explains the scripted problem to the technician. The student/technician should write down the symptoms and question the customer about the problem.

- Show the tools and materials used for soldering, and demonstrate their correct use.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

Suggested Activities

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Academic & Workplace Skills for M/H Truck Technicians.* Herndon, VA: National Automotive Technicians Education Foundation (NATEF), 1995.
- Chrysler Corp., *Body Electronics, Student Reference Book*, 1994.
- Chrysler Corp., *Body Electronics, Electronic Clusters.*
- Chrysler Corp., *Body Electronics, Electronic Pinion.*
- Chrysler Corp., *Body Electronics, Student Reference Book*, 1994.
- Duffy, James E. *Auto Electricity, Electronics, Computers.* South Holland, IL: Goodheart-Willcox Co., Inc., 1989.
- Ford Motor Co. *Automotive Electronics Reference Book*, 1991.
- General Motors. *Applied Automotive Electronics*, 1991.
- General Motors. *Specialized Electronics Training (S.E.T.), Student Workbook*, 1995.
- General Motors. *Specialized Electronics Training (S.E.T.), Instructor's Guide*, 1995.
- General Motors. *Specialized Electronics Training (S.E.T.), Contents*, 1995.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual, 2nd Ed.* Albany, NY: Delmar Publishers, 1996.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual, 2nd Ed.* Albany, NY: Delmar Publishers, 1996.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*, 1st ed. Albany, NY: Delmar Publishers, 1999.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Identify Types of Circuits and Circuit Devices on a Circuit

1. Series/parallel
2. Headlight switch, headlight dimmer switch
3. Series/parallel
4. The 4 power window motors
5. Series/parallel
6. At the base of the wiper motor module
7. Series/parallel
8. Circuit breaker, master switch assembly, LH front window switch
9. Circuit breaker, master switch assembly, LH rear window switch
10. Left and right front park/turn lights (2), license lamps (2), left and right rear park/stop/turn lamps (4), left and right rear side
11. High mount stop lamps (2); left and right rear park/stop/turn lamps (4)
12. Hot at all times
13. Hot in run
14. Series/parallel
15. Fuse, horn relay, horns (2), clock spring, horn switch

Assignment Sheet 2

Perform Calculations Using Units of Electrical Measurement

Answers for Current

1. .788 mA
2. 788 μA
3. .00005 A
4. .011 A
5. .000750 mA

6. .30025 µA

7. 11.00055 mA

8. 14.990 Amps

9. 16,000,000 µA

10. 235 MA

Answers for Voltage

11. .5 MV

12. .243 V

13. 10,000 mV

14. 3,000 kV

15. 3,000,000 V

16. .0003 kv

17. 500,000.243 V

18. 44.757 V

19. 1000 V

20 1 kV

Answers for Resistance

21. 32,000 Ω

22. 32,000,000 Ω

23. 3.5 kΩ

24. 3,500 Ω

25. 2.2 kΩ

26. 11,000 Ω

27. 1999.9 Ω

28 120,000 Ω

29. 63,000 kΩ

30. .011 Ω

Assignment Sheet 3

Prepare to Measure Current, Voltage, Resistance, and Frequency With a Multimeter

1. negative lead to "comm" jack and positive lead to V/Ω jack
2. positive (red) lead to the positive side of the battery and the negative (black) lead to the negative side of the battery
3. The fuse should be removed. The ignition switch should be placed in the open position, and the ammeter should be hooked up to the connections of the fuse holder. The positive lead should be connected to the positive side and the negative lead to the negative side of the fuse holder.
4. The positive lead of the voltmeter should be connected to the positive terminal of bulb 1 and the negative lead should be connected to the negative terminal of bulb 1.
5. the positive lead to the positive terminal of bulb 1 and the negative lead to the negative side of the battery or a good ground
6. Connect the negative (black) lead to the "comm" jack and the positive (red) lead to the "10A" jack or the 300mA jack, depending on what range of current you are measuring.
7. Remove the lamp from the circuit or disconnect power from the circuit, connect the ohmmeter to the positive and negative side of lamp 1 and read the resistance.
8. The positive lead should be connected to splice 1 and the negative lead should be connected to the positive terminal of lamp 2.
9. the fuse
10. This would indicate high resistance on the ground circuit between splice 2 and the negative side of the battery.
11. Measure the resistance of the circuit between splice 2 and the negative side of the battery.
12. fuse 2
13. Turn the knob to the Ω position.
14. The positive lead to the positive terminal of the horn switch and the negative lead to the negative terminal of the horn switch; you will have to close the switch to get the proper voltage drop reading.

Answers to Assignment Sheets

15. The positive lead should be connected to the positive terminal of horn 1 and the negative lead to the negative side of the battery or a good ground.

16. Frequency

17. VSS

Assignment Sheet 4

Calculate Resistance in Sample Circuits

1. 6
2. 1
3. 4
4. 4
5. 2
6. 3
7. 3
8. 1
9. 12
10. 2

Assignment Sheet 5

Calculate Current in Sample Circuits

1. 2
2. 3
3. 4
4. 1
5. 5
6. 1.2
7. 20
8. 24
9. 24
10. 38

Assignment Sheet 6

Calculate Voltage Drop in Sample Circuits

1. 12
2. 6
3. 4
4. 4
5. 12
6. 5
7. 5
8. 3
9. 12
10. 9.6

Assignment Sheet 7

Calculate Voltage in Sample Circuits

1. 24
2. 12
3. 18
4. 16.465
5. 12
6. 18
7. $2.666\underline{6}$
8. 13.5
9. 3
10. 25.714285

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to developing basic diagnosis and repair skills to their correct definitions. Write the number of the correct answer in the blank.

1. Calibrate
2. Continuity
3. Functionality
4. Shunt/current clamp
5. Spiking

____ a. Capable of performing its function. In relation to a test instrument: the instrument works

____ b. To check and adjust a measuring instrument by comparing it with a standard

____ c. A sudden, sometimes large, flow of voltage in a circuit

____ d. A device that can be used with a DVOM to increase the current measuring ability of the meter

____ e. Refers to the circuit being continuous with no open

Objective 2

Match types of common circuits to their electrical characteristics. Write the number of the correct answer in the blank. Characteristics continue on the next page.

1. Series circuit
2. Parallel circuit
3. Series-parallel circuit

____ a. If the current is damaged or broken in the main line, all current will stop to the other circuit elements.

____ b. If a load is broken or damaged, the circuit does not break as current can flow through another path to the other loads.

____ c. The voltage drop varies directly with the resistance.

____ d. Total current is the sum of the currents in the branches and the current in a branch varies inversely with the resistance of the branch.

____ e. If the circuit is broken or damaged in one of the branch parts, it will not stop the current flowing through the other branches or the main line.

____ f. Current flows through one path (main line) to reach a number of paths (branches).

____ g. Current flows from the power source through one path to all of the circuit elements.

____ h. The resistance equals the sum of individual resistance.

____ i. To determine values of current, voltage, and resistance, the circuit is broken down into an equivalent series circuit, identifying which are series components and which are parallel components.

____ j. Total voltage drop is the same across all branches.

____ k. Current flows through a number of paths (branches) to reach all of the circuit elements.

____ l. If one load is broken or damaged, all of the circuit is broken, and all other loads on that circuit will not operate, even though they are not damaged or broken.

____ m. The sum of the voltage drops equals the applied voltage.

____ n. Total resistance is always less than the resistance of any branch.

Objective 3

Describe common problems with electrical circuits (types, symptoms, causes). Write the number of the correct answer in the blank. Definitions continue on the next page.

1. open
2. short-to-ground
3. short-to-voltage
4. high resistance

____ a. **Description**: Uninsulated sections of two circuits physically touch each other, allowing the voltage from one circuit to power the other.
Symptoms: Various and mysterious
Frequent causes: Damaged insulation, improper wiring, corroded conductor or connector

____ b. **Description**: An unintended circumstance increases resistance in the current.
Symptoms: Current in the circuit is at a lower level than normal.
Frequent causes: Dirt or corrosion on connectors or terminals, loose conductors, damaged wires, bent or loose terminals, terminals improperly crimped, improper wiring, broken connector lock

____ c. **Description**: The circuit is physically broken at some point, causing a gap across which the current cannot flow.
Symptoms: Various and mysterious
Frequent causes: Broken, loose or corroded conductors, blown fuses or tripped circuit breakers, internally open loads or control devices

____ d. **Description**: An uninsulated part of a circuit touches the ground path, causing the current to flow into the ground path rather than continue in the circuit.
Symptoms: No current flows in the circuit or the circuit cannot be turned off.
Frequent causes: Damaged insulation, improper wiring, corroded conductor

Objective 4

Distinguish among types of electrical diagnostic instruments (names and illustrations, usage, calibrated vs. tested requirement). Write the number of the correct answer in the blank. Definitions continue on the next page.

1. 12-volt test light
2. Harness pinout box
3. Digital storage oscilloscope
4. (DVOM) Digital multimeter
5. Jumper wires
6. Vehicle interface module
7. Logic probe
8. Scan tool
9. Self-powered test light

____ a. **Description of use**: Used to bypass part of a circuit.
Problems that can be diagnosed: Opens, shorts
Rules for handling: Never connect across a battery. This could cause the battery to explode.
It is highly recommended that you only use one containing a circuit breaker or fuse to prevent personal injury and damage to the circuit.
Never use to bypass a load unless required by a specific procedure.
Do not use without a fuse to bypass a protection device. Circuit damage may result.
Be careful when handling the end located away from the power source (the positive side) so that you don't accidentally touch a ground path and cause a short in the circuit you are testing.
Always use the correct mating terminals on jumpers when testing a circuit terminal. This will prevent damage to the terminal and allow you to obtain a truer reading.
Test for functionality before use? yes
Calibrate before use? no

____ b. **Description of use**: Used to detect and measure current, voltage, or resistance in a circuit or circuit device.
Problems that can be diagnosed: opens, shorts to ground, shorts to voltage, resistance problems, amperage usage, frequency output problems, identify voltage source
Rules for handling: Always follow manufacturer's instructions when operating.
Handle carefully. They can be easily damaged.
When using the ohmmeter function, never connect to a circuit or component connected to a power source.
When using the ammeter function, never bypass a load.
Always use the proper terminal ends on test leads to obtain correct readings and not damage the terminal.
If multimeter comes with a protective case, use multimeter with case attached.
When testing for frequency, never connect the multimeter to a circuit or component connected to a power source.
Test for functionality before use? yes
Calibrate before use? yes

____ c. **Description of use**: Connects to the vehicle's computer and displays diagnostic information to the technician.
Problems that can be diagnosed: opens, shorts to ground, shorts to voltage, problems with the vehicle's computer
Rules for handling: Always follow manufacturer's instructions when operating.
Handle tools carefully. They can be easily damaged.
Always refer to service manual when interpreting diagnostic codes and information.
Always unplug the tool from the power source before changing the cartridge unless otherwise stated in the operator's manual.
Test for functionality before use? yes
Calibrate before use? no

____ 4. **Description of use**: Used to check for the presence of voltage or a ground in a circuit.
Problems that can be diagnosed: opens, shorts to ground
Rules for handling: Be careful of the sharp tip of the probe; injury may result.
Do not use a test light in a circuit containing electronic circuit devices or a computer unless the vehicle's service manual specifically calls for its use.
Test for functionality before use? yes
Calibrate before use? no

____ e. **Description of use**: Used to check for continuity in a circuit or circuit device that is not connected to a power source.
Problems that can be diagnosed: opens, shorts
Rules for handling: Be careful of the sharp tip of the probe. Injury may result.
Do not connect to a circuit or circuit device connected to voltage. The bulb in the test light will be damaged.
Circuits or circuit devices with too much resistance will not light the lamp of a self-powered test light because it uses low voltage.
Do not check circuits and components that operate on milliamperes (computer circuits). The current of the light will damage the circuit or components.
Test for functionality before use? yes
Calibrate before use? no

____ f. **Description of use**: Used to check continuity in circuits transmitting digital signals to and from computers.
Problems that can be diagnosed: opens, inappropriate voltage level, existence of digital signals in the circuit, existence of a ground
Rules for handling: Be careful of the sharp tip of the probe. Injury may result.
Always follow manufacturer's instructions when connecting the logic probe.
Test for functionality before use? yes
Calibrate before use? no

____ g. **Description of use**: Used to isolate the piece of equipment being tested from the vehicle. The equipment can be operated without vehicle controls while still mounted in the vehicle.
Problems that can be diagnosed: shorts to ground or voltage, opens
Rules for handling: Always follow manufacturer's instructions for the vehicle and the equipment being tested.
Always refer to the service manual when interpreting diagnostic/fault codes.
Always unplug the module's power source before connecting or disconnecting the module from the vehicle or equipment.
Test for functionality before use? yes
Calibrate before use? yes

____ h. **Description of use**: Designed to save, print, measure, and compare the waveform to other waveforms of voltage changes in a circuit over time
Rules for handling: Always follow manufacturer's instructions as not all connect to the circuit in the same way.

____ i. **Description of use**: Designed to be connected inline of the harness having a problem. Individual circuits can be tested while current is flowing through the circuit.
Problems that can be diagnosed: shorts to ground or voltage, opens
Rules for handling: Always follow the manufacturer's instructions for the vehicle or equipment being tested.
Always refer to the service manual when interpreting diagnostic/fault codes.
Take care not to damage the terminals or allow them to corrode.
Test for functionality before use? yes
Calibrate before use? no

Objective 5

Arrange the steps of electrical troubleshooting in the order in which they should be completed. Write the appropriate number (1-7) on each line.

_____ test — determine what tests are needed to check the specific section of the electrical system and test

_____ verify problem — check out the symptoms and problem as described by the client

_____ narrow — analyze the number of possibilities for the problem and eliminate problem sources by using knowledge of the specific system and basic rules of electricity

_____ verify repair — make sure the circuit is operating correctly; test drive the vehicle

_____ repair — replace a bad component, solder a broken wire, or repair a connector

_____ visualize — think of how the current flows through the circuit, each connection and each component

_____ listen — pay attention to the client as they explain how the piece of equipment is malfunctioning

Written Test

Objective 6

Arrange the steps in soldering in the order in which they should be completed. Write the appropriate number (1-7) on each line.

_____ a. Put on safety glasses and then prepare soldering iron or soldering gun by cleaning and tinning the tip with a thin coat of rosin-core solder.

_____ b. Reinsulate the connection using heat-shrink insulation and a heat gun.

_____ c. Strip wire (remove its insulation) using an electrician's stripper-crimper. Use the proper hole for the gauge of wire you are stripping to prevent nicks and cuts.

_____ d. Solder exposed pieces of spliced wiring using soldering iron or gun and rosin-core solder.

_____ e. Twist or splice the exposed wiring securely, but gently.

_____ f. Allow solder to cool and then test connection to make sure it is secure.

_____ g. Clean the exposed wiring using rosin-type cleaning-flux solution (not acid flux!) to ensure a good electrical connection.

Objective 7

Complete statements concerning guidelines for soldering by filling in the blanks with the correct answers.

a. When soldering, enough heat must be generated so the solder ____________________ and does not become pasty or mushy.

b. Move the solder along the wiring to allow the solder to cover the ____________________.

c. Use only enough solder to flow between the ____________________ to form a good bond.

d. A poorly soldered connection—a connection soldered with heat insufficient to properly heat the wire, called a ____________________— will have a dull, rough appearance.

e. Soldered connections much meet two requirements:

- Good physical connection
- ____________________.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 3
b. 1
c. 5
d. 4
e. 2

Objective #2

a. 3
b. 2
c. 1
d. 2
e. 3
f. 3
g. 1
h. 1
i. 3
j. 2
k. 2
l. 1
m. 1
n. 2

Objective 3

a. 3
b. 4
c. 1
d. 2

Objective 4

a. 5
b. 4
c. 8
d. 1
e. 9
f. 7
g. 6
h. 3
i. 2

Objective 5

5, 2, 4, 7, 6, 3, 1

Objective 6

a. 4
b. 7
c. 1
d. 5
e. 3
f. 6
g. 2

Objective 7

a. Flows freely as a liquid
b. Length of the splice
c. Wiring strands
d. Cold joint
e. Good electrical connection

Prerequisites:
None

Learning Activities Sheet

Student Name ____________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Take Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet

☐ 3. **Study** Information Sheet, Objectives 1 and 2.

☐ 4. **Do** Assignment Sheet 1, "Identify Types of Circuits and Circuit Devices on a Circuit".

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3 and 4.

☐ 6. **Read** Student Supplement 1, "Values, Prefixes, and Symbols".

☐ 7. **Do** Assignment Sheet 2, "Perform Calculations Using Units of Electrical Measurement".

☐ 8. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat steps 3 and 7.

☐ 9. **Study** Information Sheet, Objectives 3 through 5.

☐ 10. **Read** Student Supplement 2, "Multimeters".

☐ 11. **Do** Assignment Sheet 3, "Prepare to Measure Current, Voltage, Resistance, and Frequency With a Multimeter".

☐ 12. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, repeat steps 9, 10, and 11.

Learning Activities Sheet

☐ 13. **Do** Job Sheet 1, "Calibrate and Make Functionality Tests on Electrical Diagnostic Instruments".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 10 and 13.

☐ 15. **Do** Assignment Sheet 4, "Calculate Resistance in Sample Circuits".

☐ 16. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, repeat Steps 9 and 15.

☐ 17. **Do** Assignment Sheet 5, "Calculate Current in Sample Circuits".

☐ 18. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, repeat steps 9 and 17.

☐ 19. **Do** Assignment Sheet 6, "Calculate Voltage Drop in Sample Circuits".

☐ 20. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, repeat steps 9 and 19.

☐ 21. **Do** Assignment Sheet 7, "Calculate Voltage in Sample Circuits".

☐ 22. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 23. If the evaluation is not satisfactory, repeat steps 9 and 21.

☐ 23. **Do** Job Sheet 2, "Check Electrical/Electronic Circuits With Jumper Wires".

☐ 24. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat step 23.

☐ 25. **Do** Job Sheet 3, "Check Electrical Circuits With a Test Light".

☐ 26. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat step 25.

☐ 27. **Do** Job Sheet 4, "Check Voltage in Electrical/Electronic Circuits With a Multimeter".

☐ 28. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 29. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat step 27.

☐ 29. **Do** Job Sheet 5, "Check Voltage Drops in Electrical/Electronic Circuits With a Multimeter".

☐ 30. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 31. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat step 29.

☐ 31. **Do** Job Sheet 6, "Check Current Flow in Electrical/Electronic Circuits and Components With a Multimeter".

☐ 32. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 33. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat step 31.

☐ 33. **Do** Job Sheet 7, "Check Continuity and Resistance in Electrical/Electronic Circuits and Components with a Multimeter".

☐ 34. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 35. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat step 33.

☐ 35. **Do** Job Sheet 8, "Find Shorts, Grounds, Opens, and High Resistance Problems in Electrical/Electronic Circuits".

Learning Activities Sheet

☐ 36. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 37. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 8 and repeat step 35.

☐ 37. **Study** Information Sheet, Objectives 6 and 7.

☐ 38. **Read** Student Supplement 3, "Stripping, Splicing, Crimping, and Soldering", and Student Supplement 4, "Wire Connectors".

☐ 39. **Do** Job Sheet 9, "Tin a Soldering Iron or Gun".

☐ 40. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 41. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 9 and repeat step 39.

☐ 41. **Do** Job Sheet 10, "Inspect, Test, Repair, and Replace Switches, Connectors, Terminals, and Wires of Electrical/Electronic Circuits."

☐ 42. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 43. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 10 and repeat step 41.

☐ 43. **Do** Job Sheet 11, "Inspect, Test, and Replace Fusible Links, Circuit Breakers, and Fuses".

☐ 44. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 45. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 11 and repeat Step 43.

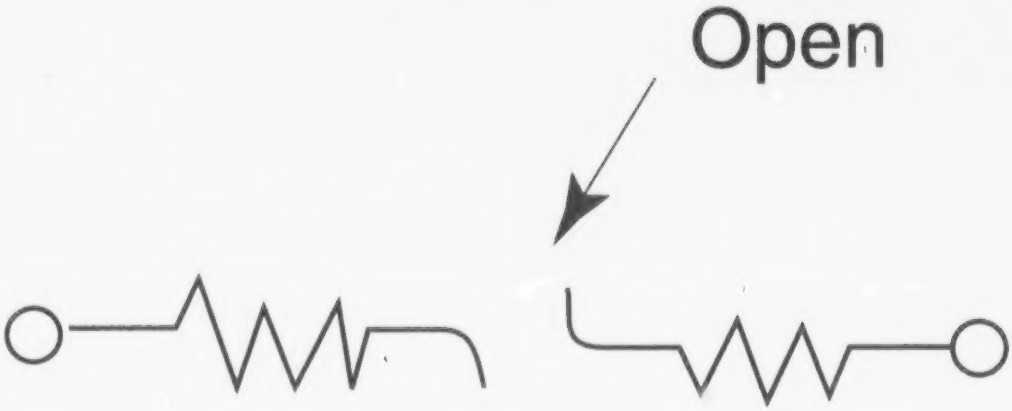
☐ 45. **Check** With instructor for any additional assignments to be completed.

☐ 46. **Take** Posttest provided by instructor. After the test has been evaluated, follow instructor's recommendations.

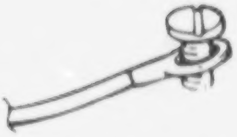
☐ 47. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next Learning Activities Sheet. If evaluation is not satisfactory, ask instructor for further instructions.

*Permission to duplicate this form is granted.

Open Circuit
(Wiring Diagram Symbol)

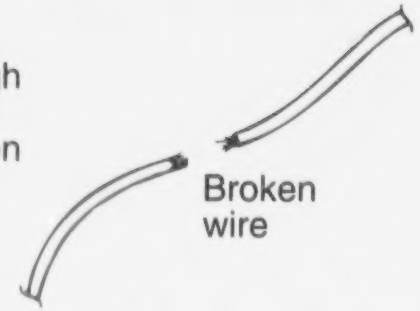


Open Circuit
(Causes)

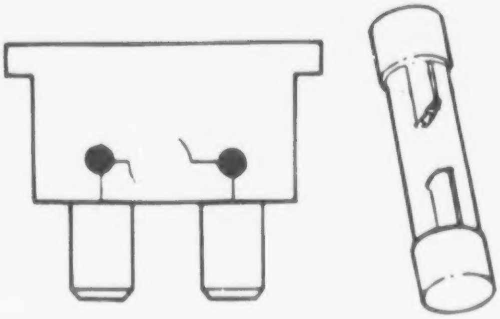


Loose connection

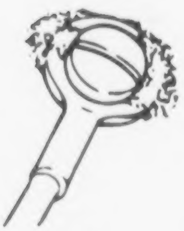
(Extremely high resistance will appear as open circuit.)



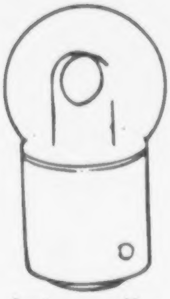
Broken wire



Blown fuses



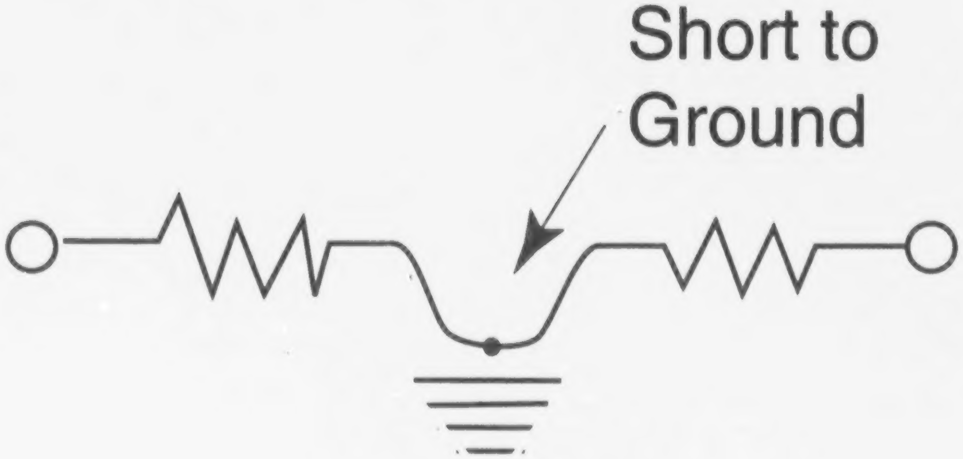
Corroded connection



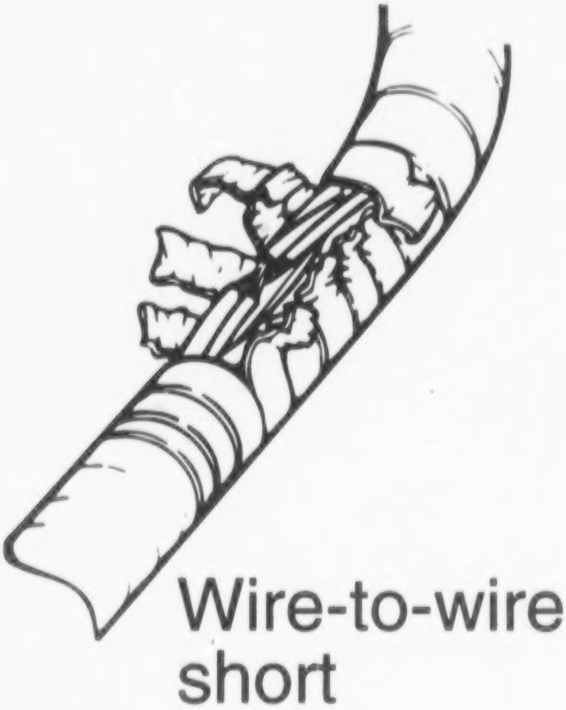
Internally open part

Used with permission of DaimlerChrysler Corp.

Short to Ground

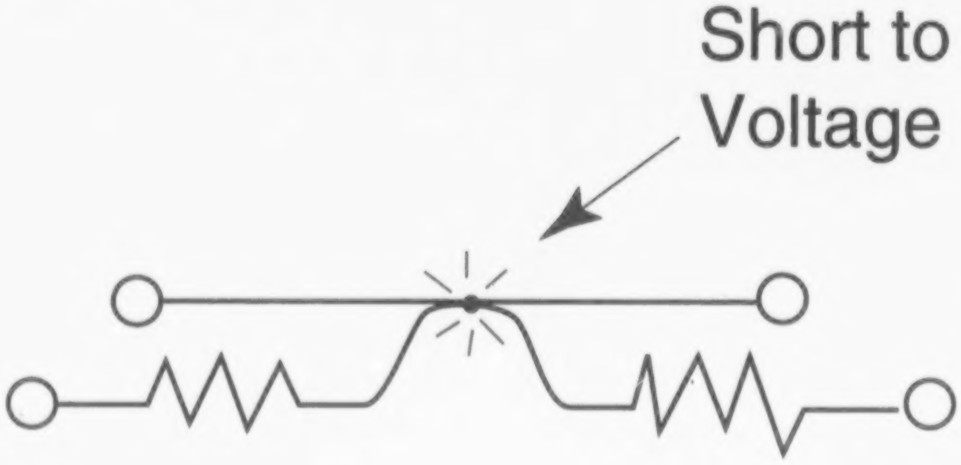

Short to Ground

Wire-to-Wire

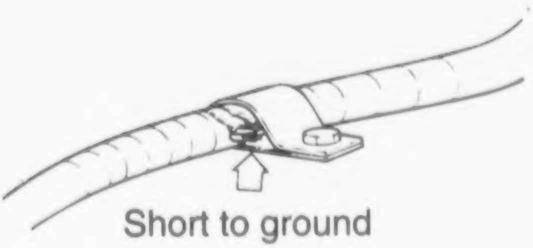

Wire-to-wire
short

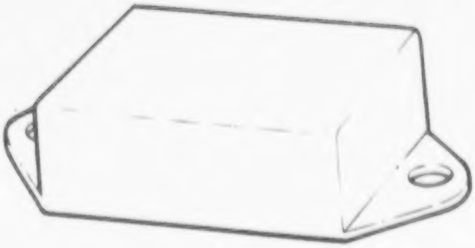
Used with permission of DaimlerChrysler Corp.

Short to Voltage


Short to Voltage

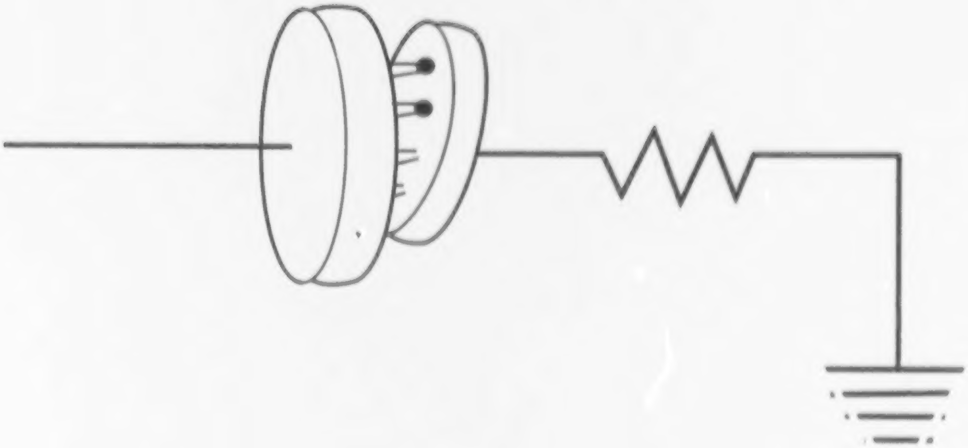
Typical Short Circuits


Short to ground

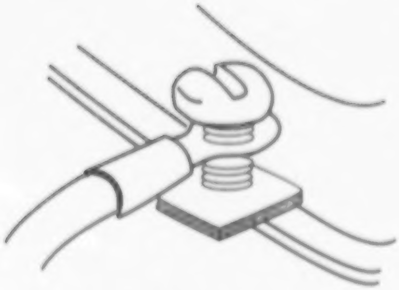

Internally shorted part (often shows no sign of failure)

Used with permission of DaimlerChrysler Corp.

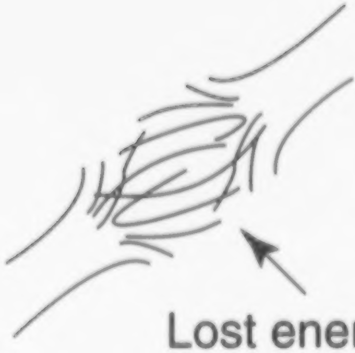
High Resistance Problems Icon



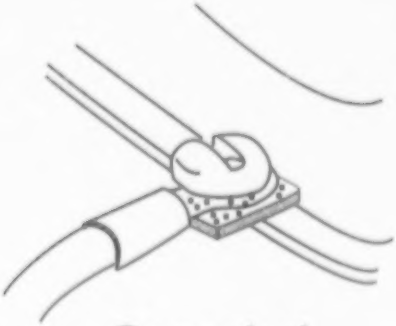
Typical High Resistance Problems



Poor or loose connections

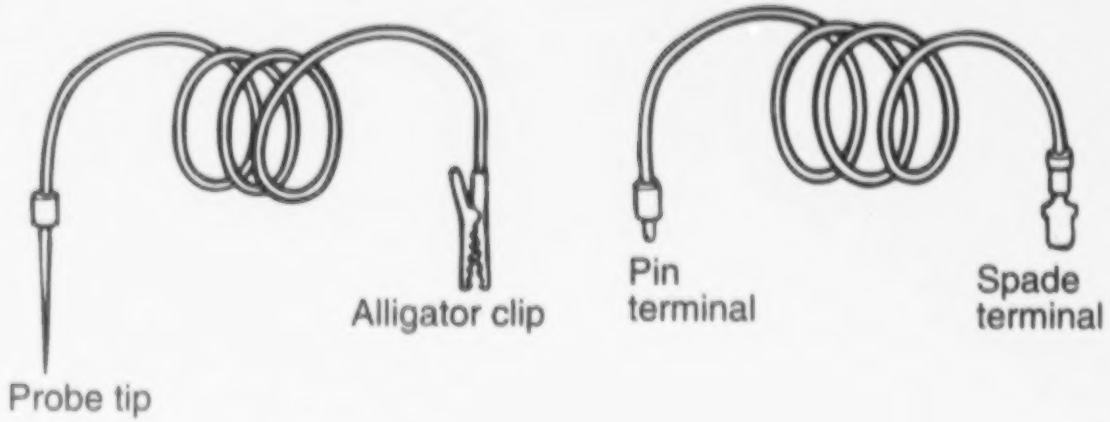


Lost energy through heat damaged wires



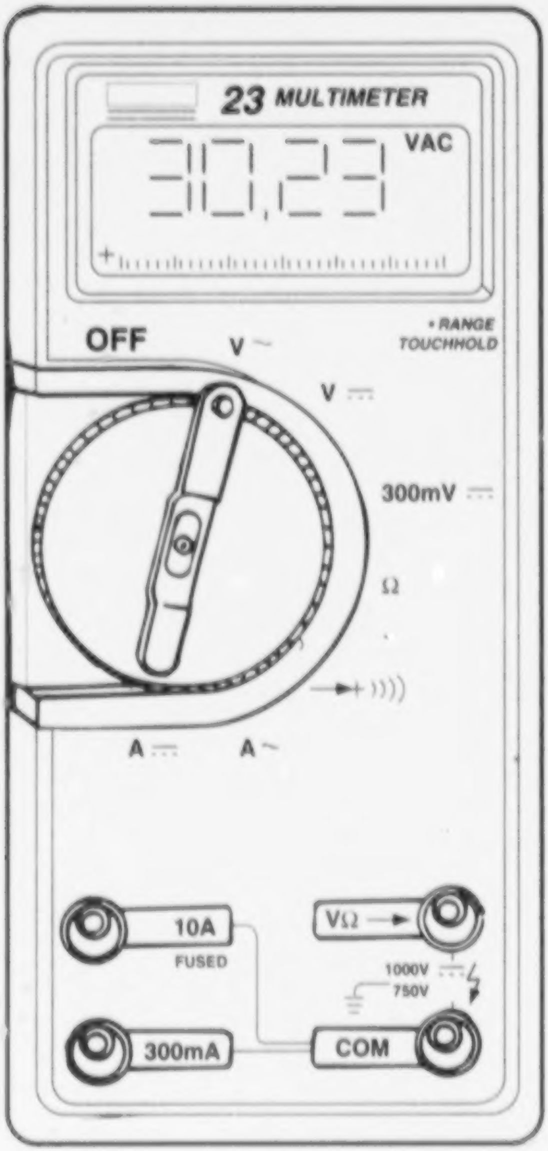
Corroded connections

Jumper Wires


Probe tip
Alligator clip
Pin terminal
Spade terminal

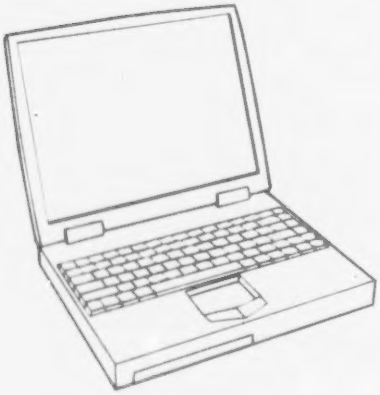
Used with permission of Ford Motor Co.

Digital Multimeter

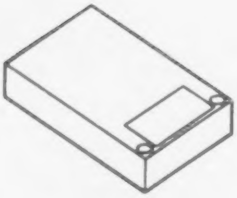

23 MULTIMETER
30.23
VAC
OFF
V ~
• RANGE
TOUCHHOLD
V ⎓
300mV ⎓
Ω
→+))))
A ⎓
A ~
10A
FUSED
VΩ →
1000V ⎓
750V
300mA
COM

Used with permission of DaimlerChrysler Corp.

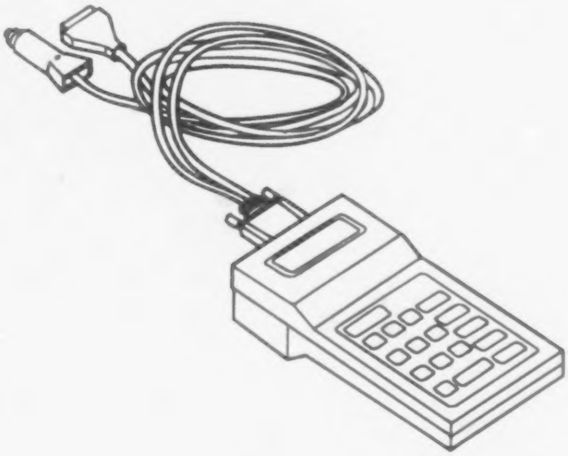
Scan Tools



Laptop computer

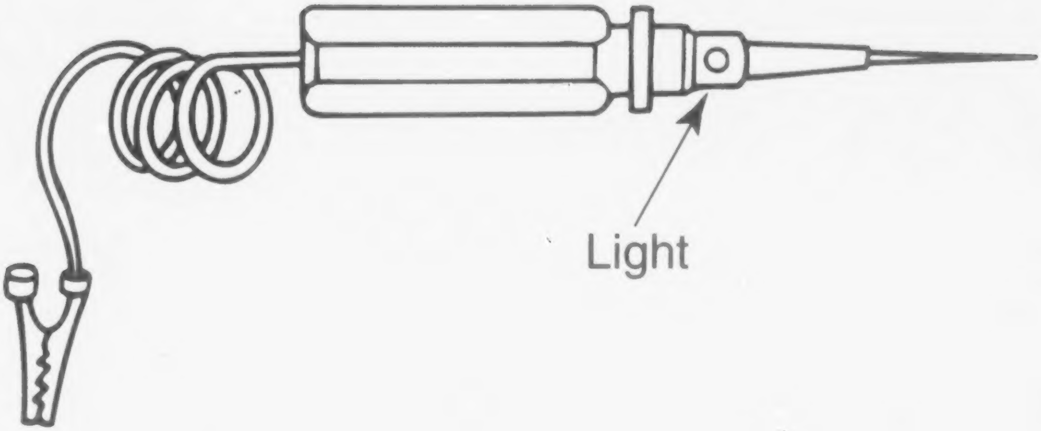


Diagnostic
cartridge



Scan tool

12-Volt Test Light



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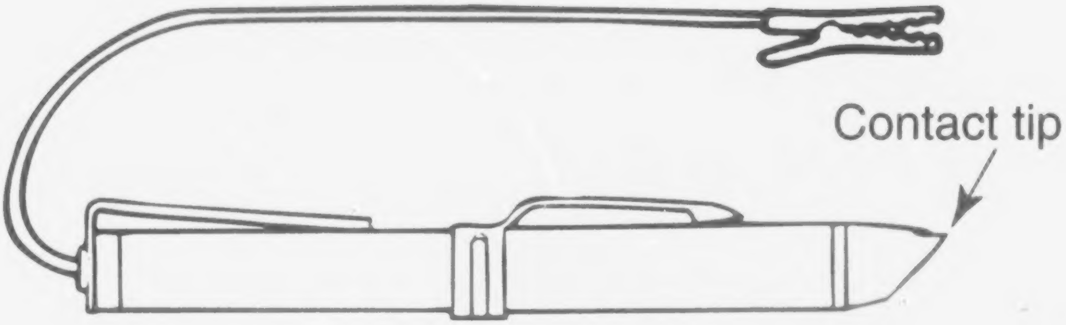
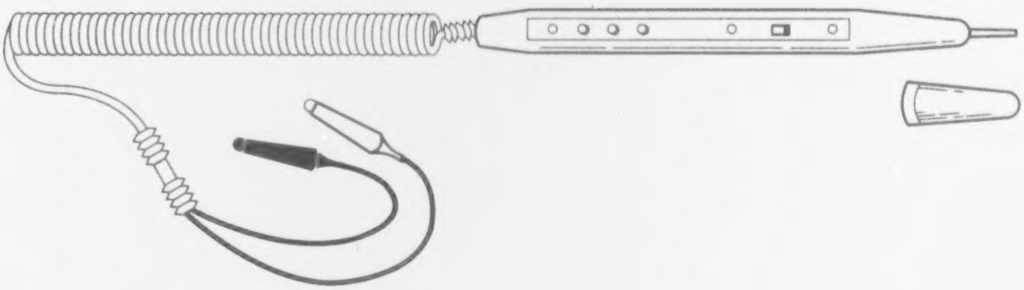
273

Self-Powered Test Light

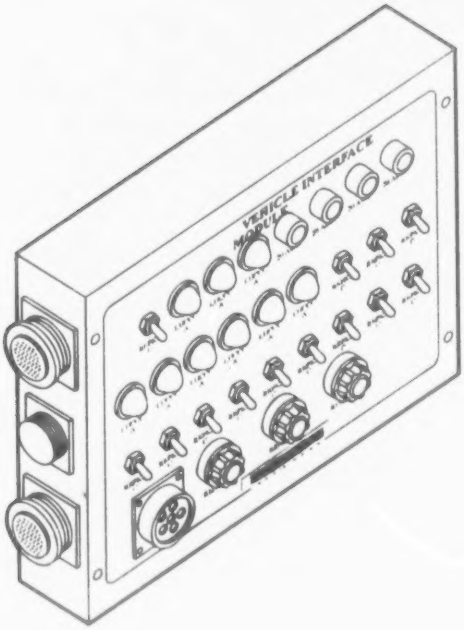


Used with permission of Ford Motor Co.

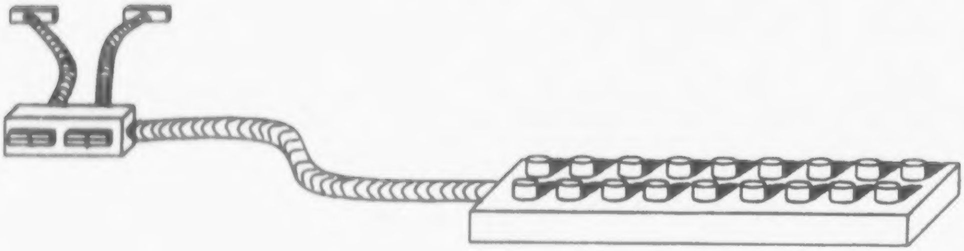
Logic Probe



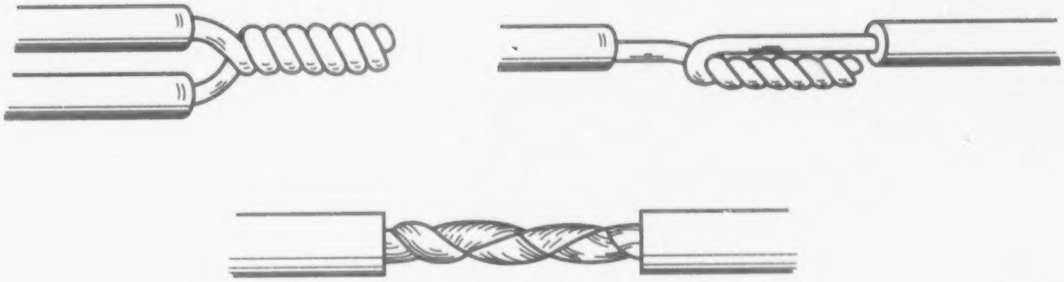
Vehicle Interface Module


VEHICLE INTERFACE MODULE

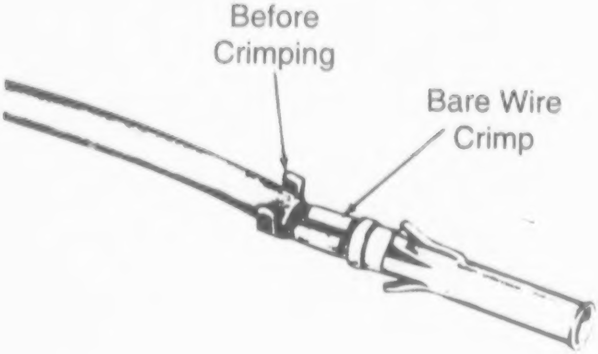
Harness Pinout/Breakout Box

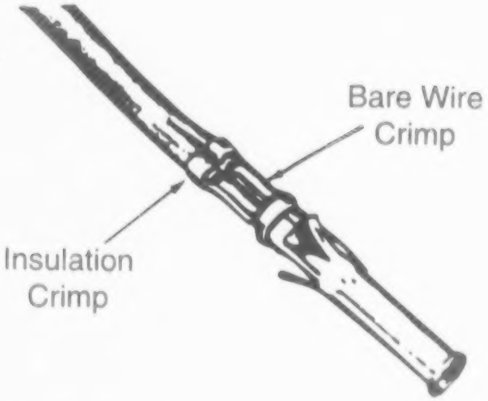


Spliced Wires



Open-Barrel Crimping


Before
Crimping
Bare Wire
Crimp


Bare Wire
Crimp
Insulation
Crimp

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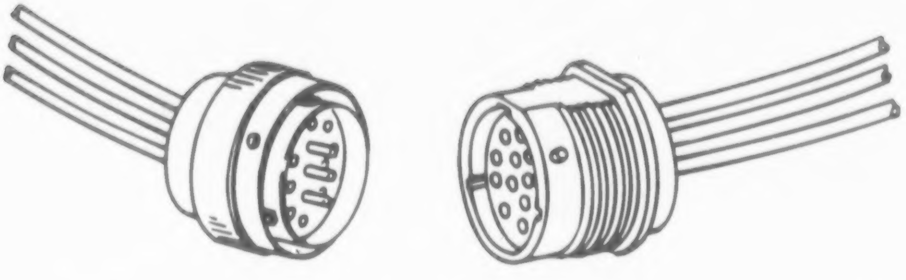
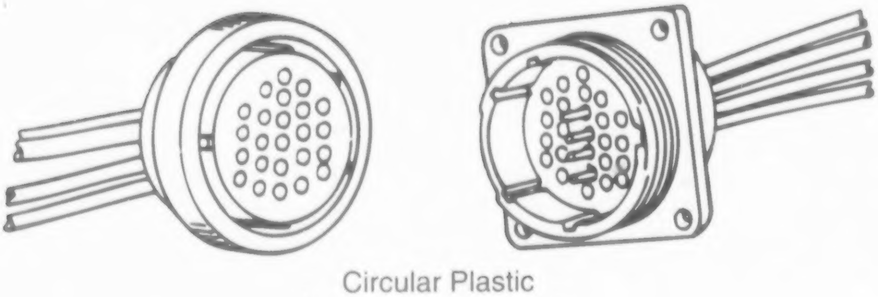
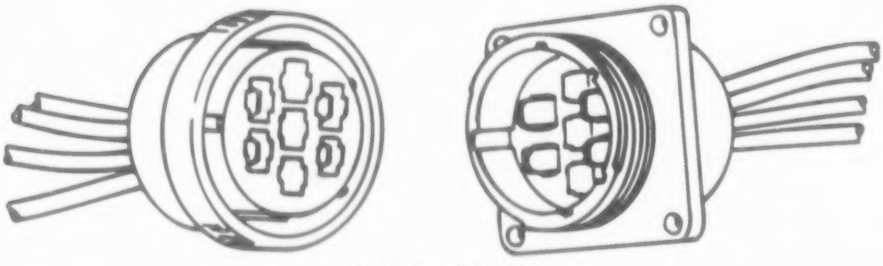
Wire Connectors



Deutsch™



Circular Plastic
for Pin-Type Contacts



Circular Plastic
for Blade-Type Contacts

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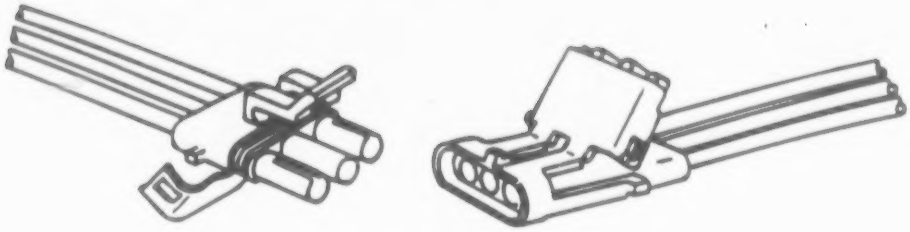
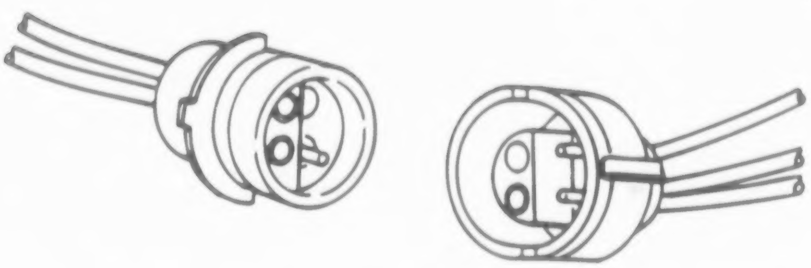
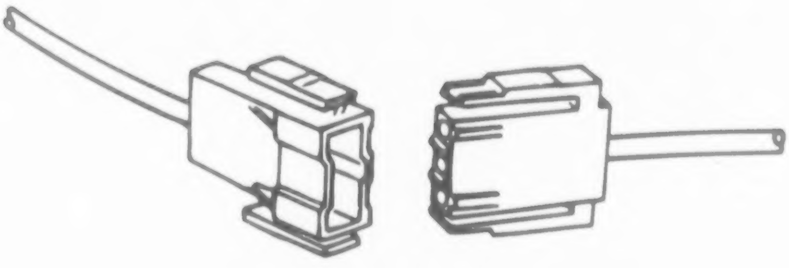
Wire Connectors (continued)



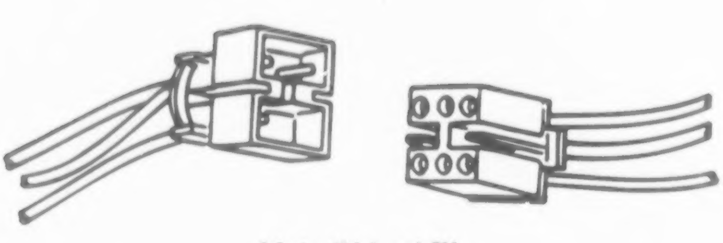
Weather Pack™



Sure-Seal™



Metrimate™



Mate-'N-Lock™

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Unit 4 Understanding Vehicle Computer Controls

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Student Components

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Diesel Engine Management System (Objective 2)
  TM 2—Analog Signal (Objective 6)
  TM 3—Digital Signal (Objective 6)
  TM 4—Serial Data (Objective 7)
  TM 5—Serial Data Transfer (Objective 7)
  TM 6—Parallel Data (Objective 7)
  TM 7—Parallel Data Transfer (Objective 7)
  TM 8—Communications Map (Objective 8)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Suggested Activities

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Show students examples of vehicle computers, sensors, and actuators and where they are located on a vehicle.
- Show students different types of sensors (pulse generator, potentiometer, thermistor, etc.) and how they differ in the way they operate and why they're used in particular locations.
- Show students different types of actuators (relay, solenoid, motor, etc.) and how they differ in the way they operate.
- Discuss how sensors, actuators, and computers, work together to keep the vehicle operating efficiently.
- Demonstrate how to connect a scan tool or computer to the vehicle to retrieve fault code information.
- Demonstrate how to connect a voltmeter and test light to a vehicle to retrieve fault codes, and how to interpret the pulses on a voltmeter or flashes on a test light.
- Have students practice reading the flash codes of a Check Engine Light and then have them look up the fault codes in the appropriate service manual.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

Suggested Activities

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Academic & Workplace Skills for M/H Truck Technicians.* Herndon, VA: National Automotive Technicians Education Foundation (NATEF), 1995.

- Chrysler Corp., *Body Electronics, Student Reference Book*, 1994.

- Chrysler Corp., *Body Electronics, Electronic Clusters.*

- Chrysler Corp., *Body Electronics, Electronic Pinion.*

- Duffy, James E. *Auto Electricity, Electronics, Computers.* South Holland, IL: Goodheart-Willcox Co., Inc., 1989.

- Ford Motor Co. *Automotive Electronics Reference Book*, 1991.

- General Motors. *Applied Automotive Electronics*, 1991.

- General Motors. *Specialized Electronics Training (S.E.T.), Student Workbook*, 1995.

- General Motors. *Specialized Electronics Training (S.E.T.), Instructor's Guide*, 1995.

- General Motors. *Specialized Electronics Training (S.E.T.), Contents*, 1995.

- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual*, 2nd Ed. Albany, NY: Delmar Publishers, 1996.

- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual*, 2nd Ed. Albany, NY: Delmar Publishers, 1996.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.

- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*, 1st ed. Albany, NY: Delmar Publishers, 1999.

- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Demonstrate How a Potentiometer Functions as a Sensor

Evaluated to instructor's satisfaction

Assignment Sheet 2

Access Vehicle Fault Codes Using the Vehicle's Computerized Diagnostic System; Determine Needed Repairs

1. a. engine
   b. timing sensor
   c. voltage below normal or shorted low
   d. engine timing sensor bad

2. a. driver information systems
   b. washer fluid level
   c. out of calibration
   d. washer fluid level sensor bad or needs calibrated

3. a. fuel system
   b. fuel level
   c. erratic, intermittent, or incorrect data
   d. loose connector and/or bad sensor

4. a. driver information systems
   b. barometric pressure
   c. current above normal or circuit shorted to ground
   d. short and/or bad sensor

5. a. engine
   b. alternator voltage
   c. above normal operating range
   d. regulator bad

6. a. engine
   b. engine oil pressure
   c. below normal operating range
   d. insufficient oil pressure

Written Test

Name ______________________________

Date ____________________ Score __________

Objective 1

Match the terms related to vehicle computer controls to their definitions. Write the number of the correct answer in the blank.

1. Binary code
2. Data line
3. Microprocessor
4. Program
5. Trouble/fault code

_____ a. Computer chips or integrated circuits that use binary code to analyze data and determine what should be done

____ b. The communication link between other on-the-vehicle and off-the-vehicle computers and diagnostic tools

____ c. A number that corresponds to a malfunction identified by the computer

____ d. A simple language based on a two-digit numbering system expressed as 0 and 1, on and off, or high and low; the "language" that a computer uses to "think"

____ e. A detailed set of instructions that guide the computer's response to input signals

Objective 2

Match the basic components of a computer system to their functions. Write the number of the correct answer in the blank.

1. Microprocessor
2. Sensor
3. Actuator

_____ a. A component that gathers information about vehicle operations, converts that information into voltage signals, and sends it to the computer as input

____ b. A component that performs a task in response to an output signal; converts computer output signals (voltage) into mechanical action

____ c. A component made up of integrated circuits that are capable of making intelligent decisions within the guidelines of programmable instructions

Written Test

Objective 3

List common vehicle computers (microprocessors). Write the names of any seven (7) common computers on the lines below.

____

____

____

____

____

____

____

Objective 4

Distinguish among types of sensors by matching the type of sensor to its correct definition. Write the number of the correct answer in the blank.

1. Magnetic pulse generator
2. Potentiometer
3. Switch
4. Thermistor
5. Capacitance
6. Wheatstone bridge
7. Hall-effect

_____ a. A series-parallel arrangement of resistors that sense pressure, temperature, and mechanical strain

____ b. A resistor that varies voltage based on changes in temperature

____ c. An induction device that produces an AC voltage signal to sense speed of the monitored component

____ d. Opens or closes the circuit and can sense almost any condition

____ e. Uses a variable capacitor made of a positive and negative plate attached to electronic circuitry to sense pressure

____ f. A variable resistor that senses mechanical movement and changes it into a variable voltage signal to the computer

____ g. Uses motion to generate frequency signals as an input to monitor commonly controlled parameters

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Objective 5

Use the following abbreviations to identify the four types of actuators. Write the abbreviation for the actuator next to each statement that is true for that type of actuator. Statements may be true for more than one type of actuator.

R — relay
S — solenoid
M — motor
W — warning device

_____ a. Changes electric energy into visual energy

____ b. Changes electric current into mechanical motion

____ c. Controls high-current circuits to protect the computer

Objective 6

Distinguish between analog and digital signals. Write the number of the correct answer in the blank

1. Analog
2. Dgital

_____ a. A voltage signal that has only two possible measurements (on or off, high or low, yes or no, etc.); called a square wave

____ b. A voltage signal that is continuously variable within a certain voltage range

Objective 7

Distinguish between serial data transfer and parallel data transfer. Write the number of the correct answer in the blank.

1. Serial data transfer
2. Parallel data transfer

_____ a. The transfer of data between computers one byte (digital "word") after the other in one direction

____ b. The transfer of each element of the data at the same time on its own data line

Objective 8

Trace the flow of data through a simplified computer system in the order in which it occurs. Write the appropriate number (1-6) on each line.

_____ Time pulses from internal clocks help to separate one "message" from another

____ The computer stores the input signals in memory. It tests the input signals against known or program values. This testing process may include making calculations and comparisons

____ The computer sends one or more output signals to other computers, to the driver information system, and/or to specific actuators to carry out the decision (solenoids, relays, or motors). A digital-to-analog interface converts the digital output signal into an analog signal, if needed.

____ Input voltage signals are sent to the computer from many sources. Sources include sensors, switches, other computers, and driver-operated controls. Data links carry this information.

____ The computer retrieves stored input signals when a decision (correction or adjustment) must be made.

____ An analog-to-digital interface receives the input signals and translates them into digital binary code as needed.

Objective 9

List ways to retrieve diagnostic information from vehicle computers.

- ____________________
- ____________________
- ____________________
- ____________________

Objective 10

Place the number of the SAE number group before the description of what it identifies. Write the number of the correct answer in the blank.

1. First number group
2. Second number group
3. Third number group

____ a. Identifies whether the problem relates to current flow or voltage

____ b. Identifies which microprocessor is broadcasting the code

____ c. Identifies the parameter identifier (PID)

____ d. Identifies the message identifier (MID)

____ e. Identifies the fault mode identifier (FMI)

_____ f. Identifies the subsystem identifier

_____ g. Identifies what is wrong with the sensor signal

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 3
b. 2
c. 5
d. 1
e. 4

Objective 2

a. 2
b. 3
c. 1

Objective 3

Answer should include any seven (7) of the following:

- airbag control module
- antilock brakes and traction control module
- Antitheft/security system module
- climate control module
- engine control module
- transmission control module
- alarm/indicator module
- remote keyless entry module
- trip information module
- collision/perimeter warning module
- ground position/communication module
- rollover protection module
- instrumentation control module

Objective 4

a. 6
b. 4
c. 1
d. 3
e. 5
f. 2
g. 7

Objective 5

a. W
b. S, M
c. R

Objective 6

a. 2
b. 1

Answers to Written Test

Objective 7

a. 1
b. 2

Objective 8

3, 4, 6, 1, 5, 2

Objective 9

Answer should include all of the following in any order:

- connecting a scan tool/diagnostic computer to a diagnostic/data link connector (DLC)
- interpreting the pulses on a voltmeter
- interpreting the flashes on a test light
- interpreting the flashes of a Check Engine Light

Objective 10

a. 3
b. 1
c. 2
d. 1
e. 3
f. 2
g. 3

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objective 1.

☐ 4. **Read** Student Supplement 1, "Vehicle Computer Control Systems".

☐ 5. **Study** Information Sheet, Objective 2.

☐ 6. **Read** Student Supplement 2, "How Information Travels Among Sensors, Computers, and Actuators".

☐ 7. **Study** Information Sheet, Objectives 3 and 4.

☐ 8. **Read** Student Supplement 3, "Information Monitored by Sensors".

☐ 9. **Do** Assignment Sheet 1, "Demonstrate How a Potentiometer Acts as a Sensor".

☐ 10. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, repeat steps 7, 8, and 9.

☐ 11. **Study** Information Sheet, Objective 5.

☐ 12. **Read** Student Supplement 4, "Functions Controlled by Actuators".

Learning Activities Sheet

☐ 13. **Study** Information Sheet, Objectives 6, 7, and 8.

☐ 14. **Do** Job Sheet 1, "Use a DVOM to Measure Reference Voltage Output From the Electronic Control Module".

☐ 15. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 13 and 14.

☐ 16. **Study** Information Sheet, Objectives 9 and 10.

☐ 17. **Do** Assignment Sheet 2, "Interpret SAE Fault Codes".

☐ 18. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, repeat steps 16 and 17.

☐ 19. **Do** Job Sheet 2, "Access Vehicle Fault Codes Using the Vehicle's Computerized Diagnostic System; Determine Needed Repairs".

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 16 and 19.

☐ 21. **Check** With instructor for any additional assignments to be completed.

☐ 22. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 23. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Teacher Supplement 1—PROM Replacement

The Electronic Control Module (ECM) consists of a microprocessor that performs the computations necessary to control the ECM's functions (generate diagnostic codes, communicate with sensors and actuators, and communicate with other computers). It also contains a personality module or Programmable Memory (PROM) that provides the instructions for the ECM to do its job. These instructions contain permanent data such as shift points, gear ratios, and unique concerns about that particular vehicle. The personality module may need to be replaced if it quits functioning properly, or if changes are made to the vehicle configuration.

To replace a PROM:

1. Turn the ECM so the cover is facing up.

   Note: To avoid static electricity discharge that can damage delicate circuitry, the technician should wear special wristbands that are grounded to the ECM case by a wire and alligator clip.

2. Remove the screws from the access cover and remove the cover.
3. Using the special rocker-type PROM removal tool, engage one end of the PROM carrier with the hook end of the tool.
4. Press on the vertical bar end of the tool and rock the engaged end of the carrier up as far as possible.
5. Engage the tool on the other end of the carrier and rock the carrier in the same manner as far as possible.
6. Repeat this process until the PROM, with carriers, is free of the socket. The PROM carrier with the PROM attached should lift off the socket easily.

Note: If you have a PROM in a blue carrier, you will find a white lock on each end. Push the locks out and down to remove the carrier from the socket. If the blue carrier has a locking plate, unscrew the three screws and remove the locking plate before removing the carrier.

> Warning: DO NOT remove the small sticker on top of the PROM. Various types of light entering this area can erase information stored on the PROM.

7. Remove the new PROM and carrier from its packaging.
8. Position the new carrier squarely over the socket with the small-notched end of the carrier aligned with the narrow tab on the socket.

Note: To install a PROM with a blue carrier, match up the notches at the end of the carrier and base. Push the carrier into the socket until the locks come up, and then push both locks toward each other until they click. If so equipped, attach the locking plate to the carrier.

9. Press on the carrier until it is firmly seated in the socket. DO NOT press on the PROM itself.

300

Teacher Supplement 2—Serial Communications

The Society of Automotive Engineers (SAE) sets standards on how and what data will be sent over a data buss.

The serial communication link is used to transmit sensor and engine data to other vehicle modules, and to transmit and perform diagnostic procedures from external instrumentation such as scan tools or laptop computers.

There are three serial communication links in use in today's vehicles. Two are SAE standard J1708 links that operate at a 9.6K-baud rate. The third link is an SAE standard J1939 link that operates at a 250K-baud rate. One of the J1708 links uses the J1587 protocol while the other J1708 link uses the J1922 protocol. The J1939 data link uses the Controller Area Network (CAN) protocol.

The J1708/J1587 data link provides sensor and engine data to other vehicle modules, such as electronic dashboard displays and vehicle management systems. The link is used to transmit and perform diagnostic procedures with external instrumentation. The J1708/J1922 and J1939/CAN links exchange control data with other vehicle systems such as traction control devices and transmissions.

The following SAE documents can be used as reference material:

- SAE J1587, Electronic Data Interchange Between Microcomputer Systems in Heavy Duty Vehicle Applications
- SAE J1708, Serial Data Communications Between Microcomputer Systems in Heavy Duty Vehicle Applications
- SAE J1922, Powertrain Control Interface for Electronic Controls Used in Medium- and Heavy-Duty Diesel On-Highway Vehicle Applications
- SAE J1939, Recommended Practice for a Serial Control and Communication Vehicle Network
- SAE J1939/71, Vehicle Application Layer

The preceding publications can be ordered online at www.sae.org or by contacting the Society of Automotive Engineers at:

SAE World Headquarters
400 Commonwealth Drive
Warrendale, PA 15096-0001
Phone: (877) 606-7323 or (724) 776-4970
Fax: (724) 776-0790

Teacher Supplement 3—Diagnostics

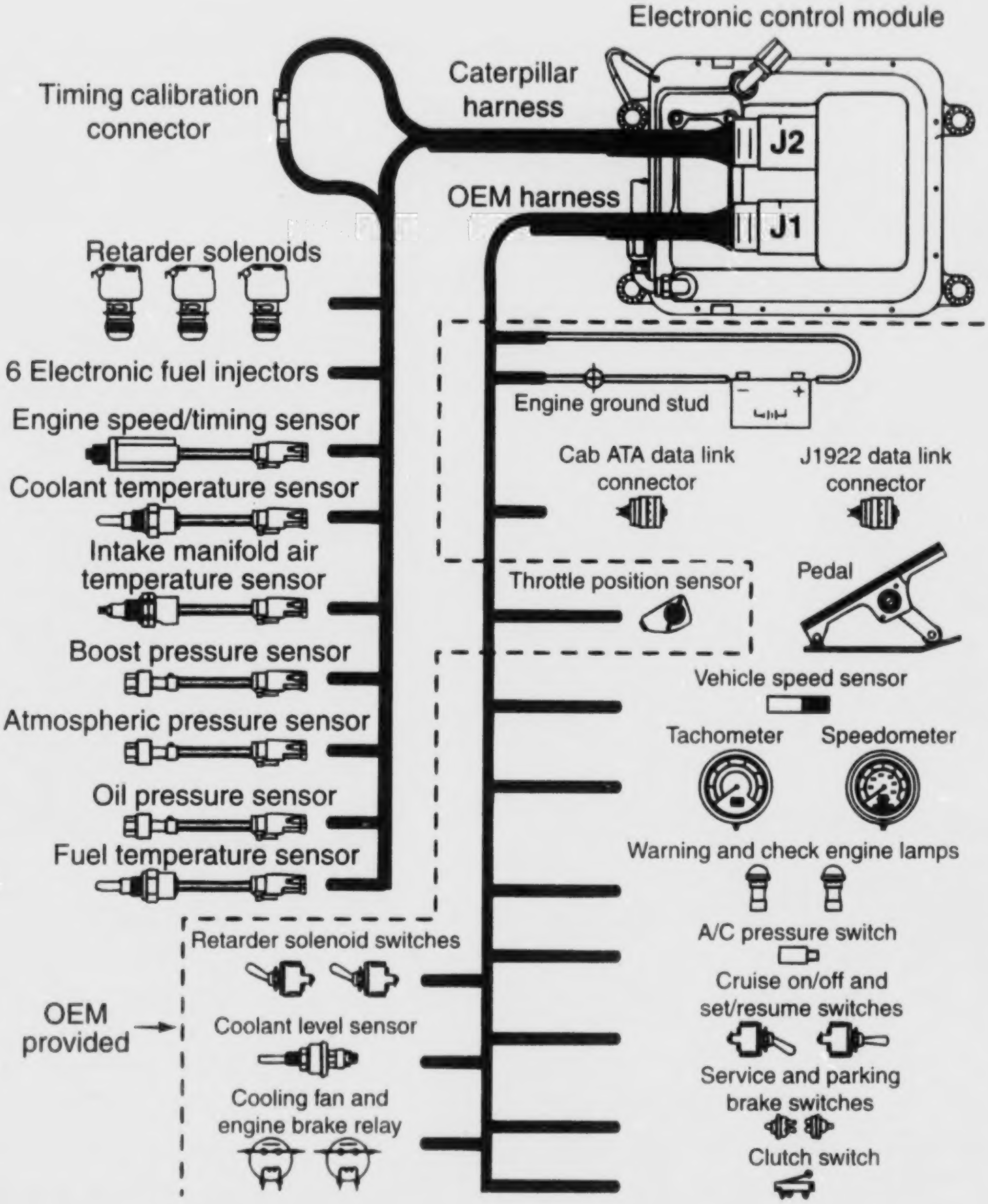
Today's heavy-duty vehicles contain microprocessors (ECM or ECU) that have diagnostic features and parameters that can be changed. In order to communicate with a vehicle's computer to display requested information and program information into the vehicle's computer, electrical technicians use a wide variety of diagnostic computers and software.

Microprocessor manufacturer's work closely with OEM's to produce software that can be loaded onto a laptop computer or build OEM specific computers. Manufacturers need to know what information the technicians want to be able to retrieve, and what information they want to be able to program into their computers. Then they build the computer or develop the software to produce those results.

Since each engine, transmission, ABS brake, etc. manufacturers have different computers or software, it would be impossible to cover them all. Always refer to the computer or software manufacturer's instructions before attempting to use their equipment.

Note: Fault/diagnostic codes may also be specific to each manufacturer. Always check the service manual before trying to interpret fault/diagnostic codes.

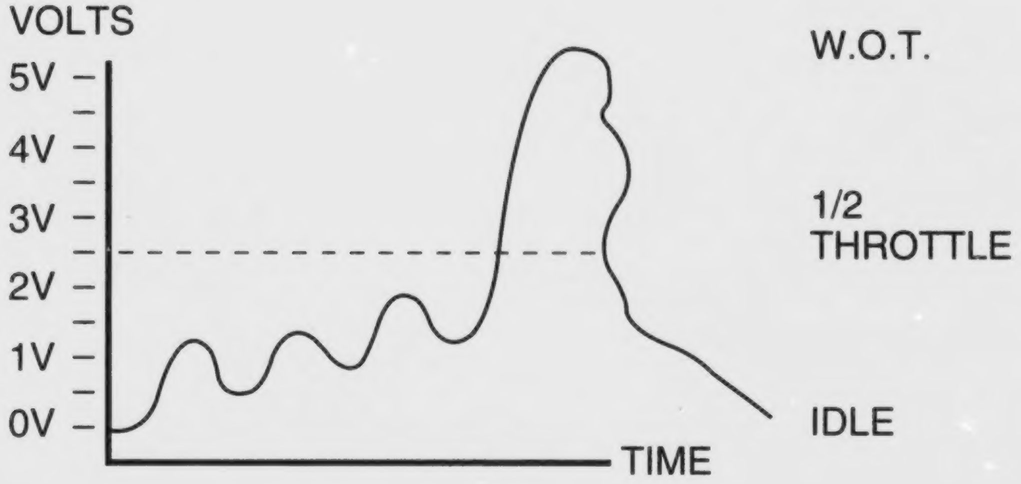
Diesel Engine Management System


Electronic control module
Caterpillar harness
Timing calibration connector
J2
OEM harness
J1
Retarder solenoids
6 Electronic fuel injectors
Engine speed/timing sensor
Coolant temperature sensor
Intake manifold air temperature sensor
Boost pressure sensor
Atmospheric pressure sensor
Oil pressure sensor
Fuel temperature sensor
Engine ground stud
Cab ATA data link connector
J1922 data link connector
Throttle position sensor
Pedal
Vehicle speed sensor
Tachometer
Speedometer
Warning and check engine lamps
A/C pressure switch
Cruise on/off and set/resume switches
Service and parking brake switches
Clutch switch
Retarder solenoid switches
Coolant level sensor
Cooling fan and engine brake relay
OEM provided

Reprinted courtesy of Caterpillar, Inc.

TM 1

Analog Signal



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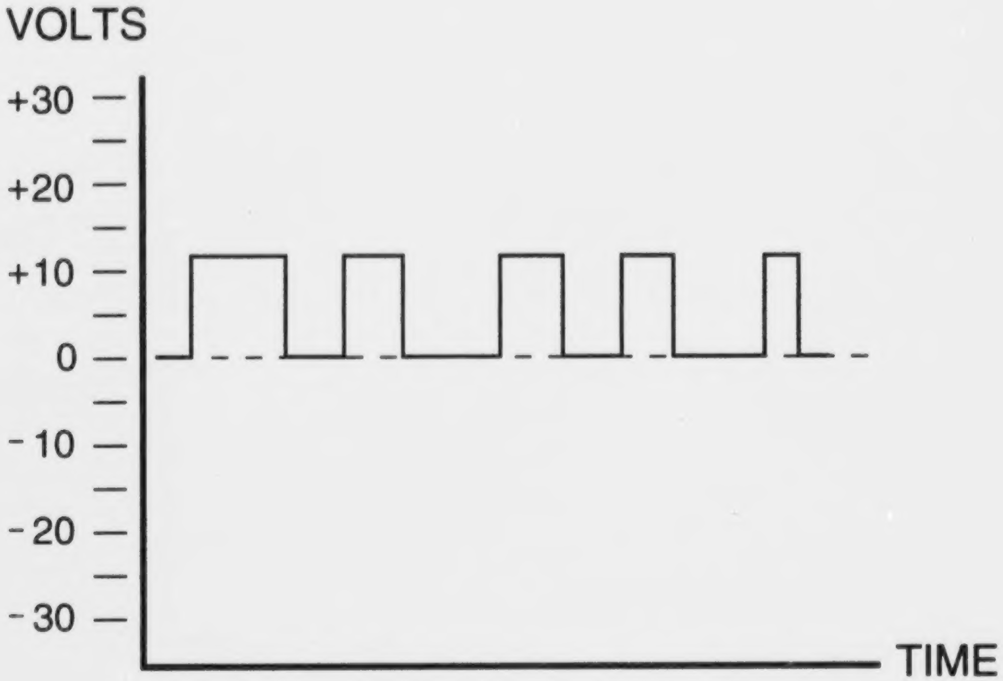
Digital Signal



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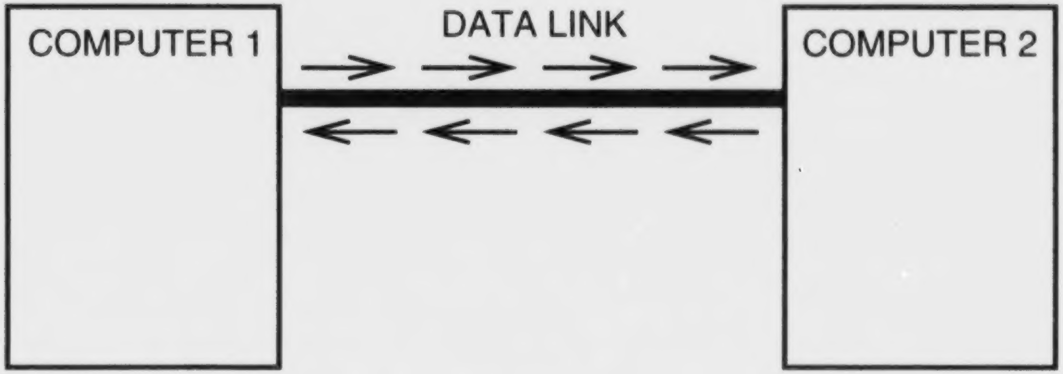
Serial Data


COMPUTER 1
DATA LINK
COMPUTER 2

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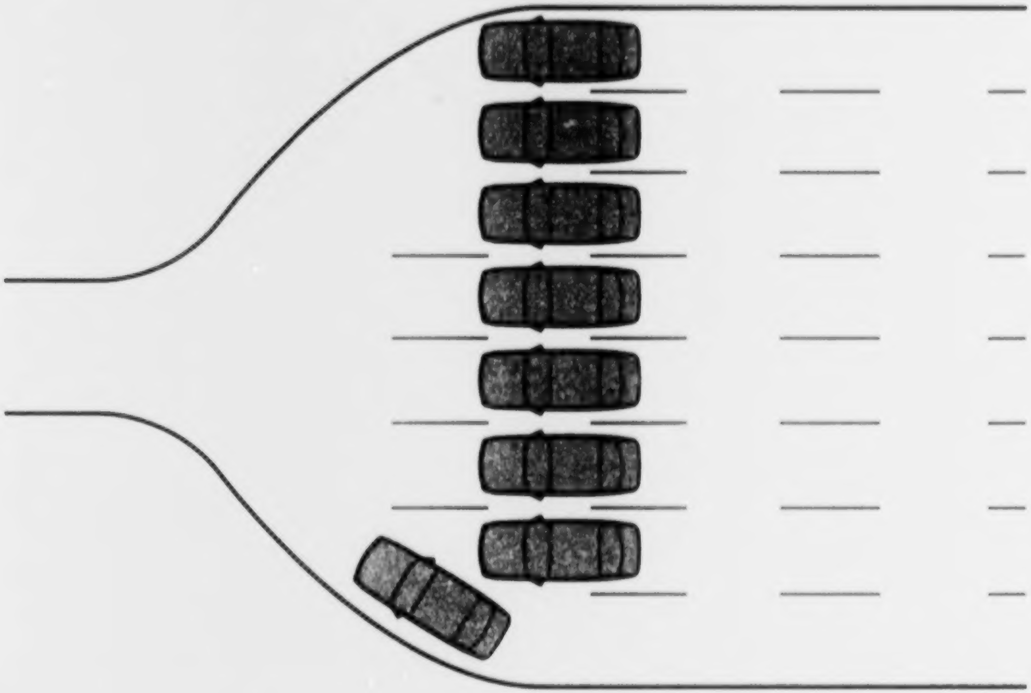
Serial Data Transfer



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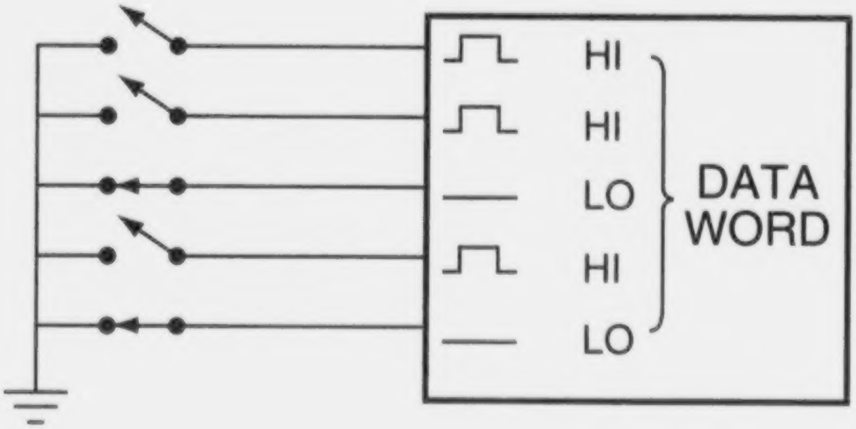
Parallel Data


HI
HI
LO
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DATA WORD

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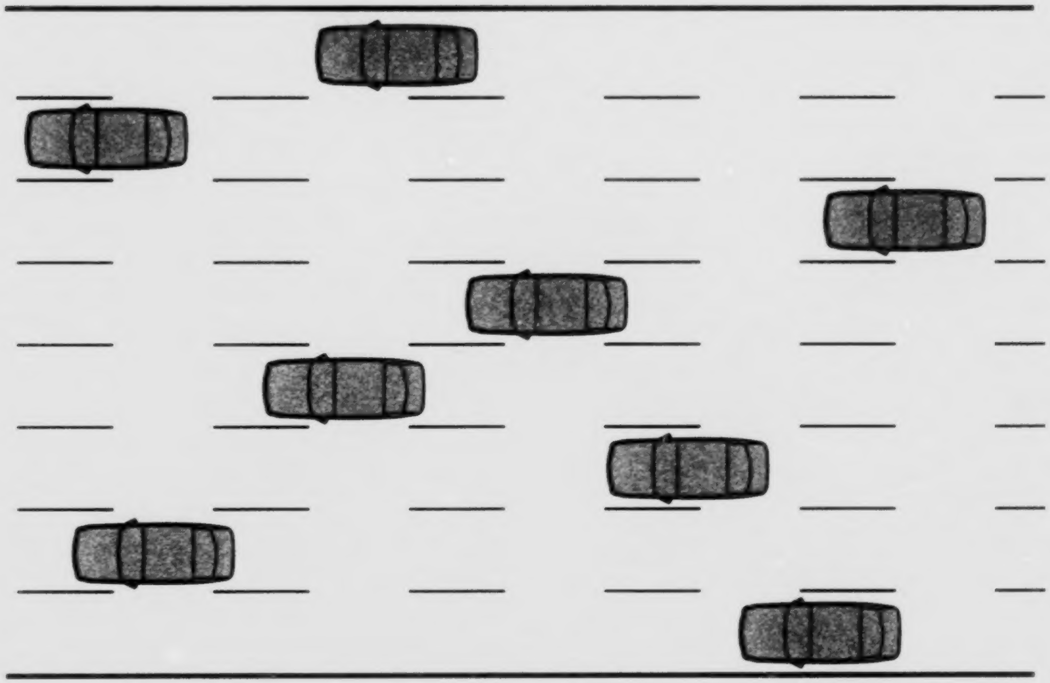
Parallel Data Transfer



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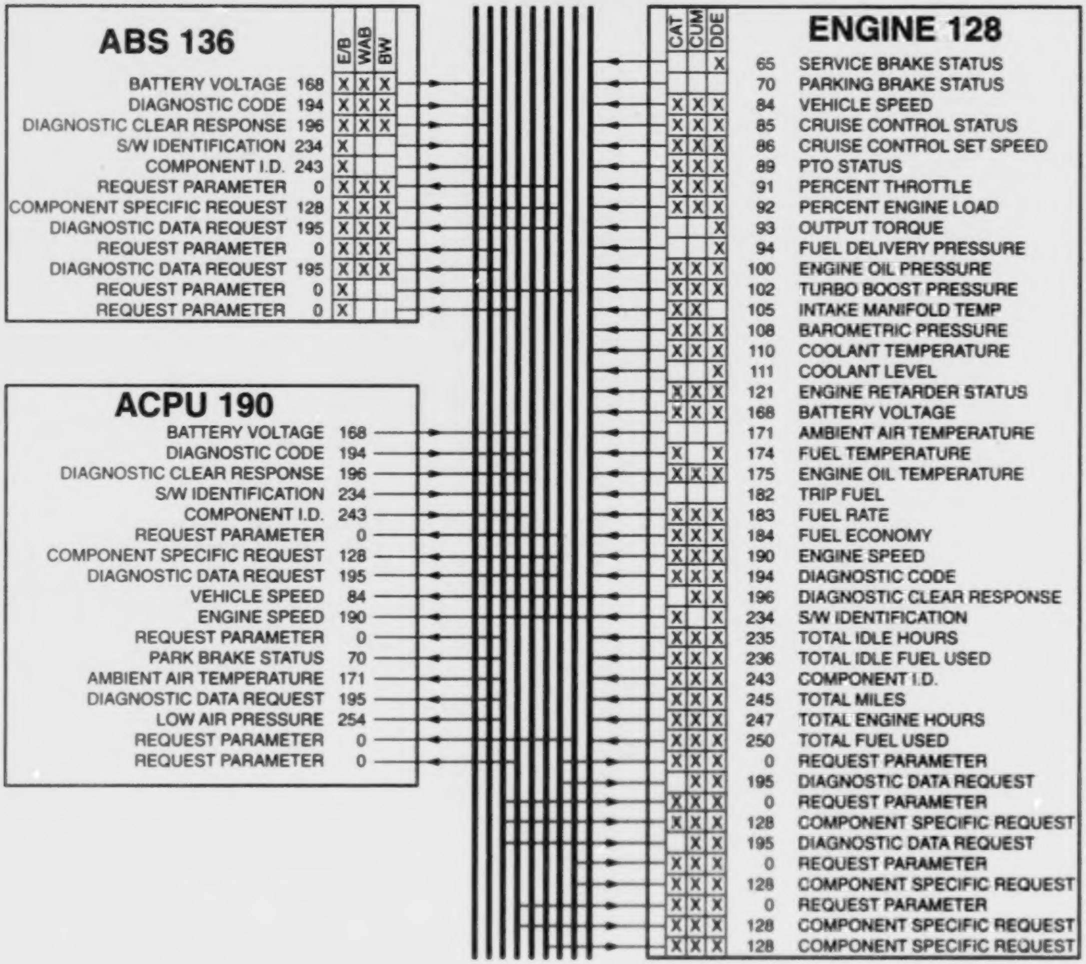
Communications Map

CENTURY CLASS J1587 COMMUNICATIONS STANDARD



ABS 136

		E/B	WAB	BW
BATTERY VOLTAGE	168	X	X	X
DIAGNOSTIC CODE	194	X	X	X
DIAGNOSTIC CLEAR RESPONSE	196	X	X	X
S/W IDENTIFICATION	234	X		
COMPONENT I.D.	243	X		
REQUEST PARAMETER	0	X	X	X
COMPONENT SPECIFIC REQUEST	128	X	X	X
DIAGNOSTIC DATA REQUEST	195	X	X	X
REQUEST PARAMETER	0	X	X	X
DIAGNOSTIC DATA REQUEST	195	X	X	X
REQUEST PARAMETER	0	X		
REQUEST PARAMETER	0	X		

ACPU 190

BATTERY VOLTAGE	168
DIAGNOSTIC CODE	194
DIAGNOSTIC CLEAR RESPONSE	196
S/W IDENTIFICATION	234
COMPONENT I.D.	243
REQUEST PARAMETER	0
COMPONENT SPECIFIC REQUEST	128
DIAGNOSTIC DATA REQUEST	195
VEHICLE SPEED	84
ENGINE SPEED	190
REQUEST PARAMETER	0
PARK BRAKE STATUS	70
AMBIENT AIR TEMPERATURE	171
DIAGNOSTIC DATA REQUEST	195
LOW AIR PRESSURE	254
REQUEST PARAMETER	0
REQUEST PARAMETER	0

ENGINE 128

CAT	CUM	DDE		
		X	65	SERVICE BRAKE STATUS
			70	PARKING BRAKE STATUS
X	X	X	84	VEHICLE SPEED
X	X	X	85	CRUISE CONTROL STATUS
X	X	X	86	CRUISE CONTROL SET SPEED
X	X	X	89	PTO STATUS
X	X	X	91	PERCENT THROTTLE
X	X	X	92	PERCENT ENGINE LOAD
		X	93	OUTPUT TORQUE
		X	94	FUEL DELIVERY PRESSURE
X	X	X	100	ENGINE OIL PRESSURE
X	X	X	102	TURBO BOOST PRESSURE
X	X		105	INTAKE MANIFOLD TEMP
X	X	X	108	BAROMETRIC PRESSURE
X	X	X	110	COOLANT TEMPERATURE
		X	111	COOLANT LEVEL
X	X	X	121	ENGINE RETARDER STATUS
X	X	X	168	BATTERY VOLTAGE
			171	AMBIENT AIR TEMPERATURE
X		X	174	FUEL TEMPERATURE
X	X	X	175	ENGINE OIL TEMPERATURE
			182	TRIP FUEL
X	X	X	183	FUEL RATE
X	X	X	184	FUEL ECONOMY
X	X	X	190	ENGINE SPEED
X	X	X	194	DIAGNOSTIC CODE
	X	X	196	DIAGNOSTIC CLEAR RESPONSE
X		X	234	S/W IDENTIFICATION
X	X	X	235	TOTAL IDLE HOURS
X	X	X	236	TOTAL IDLE FUEL USED
X	X	X	243	COMPONENT I.D.
X	X	X	245	TOTAL MILES
X	X	X	247	TOTAL ENGINE HOURS
X	X	X	250	TOTAL FUEL USED
X	X	X	0	REQUEST PARAMETER
	X	X	195	DIAGNOSTIC DATA REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
	X	X	195	DIAGNOSTIC DATA REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
X	X	X	128	COMPONENT SPECIFIC REQUEST

Courtesy of Freightliner LLC

Unit 5 Battery Diagnosis and Servicing

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Conventional Battery (Objective 4)
  TM 2—Maintenance-Free Battery (Objective 4)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss the assignment sheet. Review with students the criteria for evaluation of this activity.

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Demonstrate how to use proper protective equipment when working with batteries.

- Demonstrate the correct use of tools and equipment when servicing batteries.

- Show students that the positive battery cable is connected to the starter and the negative battery cable is connected to ground.

- Show students the difference between a corroded cable and a clean one. Show how corrosion not only gets on the terminal but also in the wire.

- Use a mock up or real batteries to demonstrate series, parallel, and series-parallel connections.

- Show a selection of batteries and how the cold cranking amps (CCA) can be different on each one. Also show how reserve capacities change from battery to battery.

- Explain how cold weather affects battery selection.

- Discuss and demonstrate how to connect a battery load tester and charger prior to the student completing the job sheets.

- Use a DVOM to measure across the terminals of a charged battery to show that a battery stores electricity. Keeping the DVOM connected, turn on the vehicles' headlights and show students how voltage drops without the engine running.

- Show students the difference between a normal draw on a battery with the engine shutdown, and a key off parasitic draw. This is best accomplished on the same vehicle by leaving the dome light or headlights on.

- Show students how the clock or radio stations loose their memory settings when the batter cable is disconnected.

- Discuss emergency jump-starting and demonstrate the procedure using an auxiliary battery and vehicle.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheet. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

Suggested Activities

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Academic & Workplace Skills for Automobile Technicians.* Herndon, VA: National Automotive Technicians Education Foundation (NATEF), 1995.
- Battery Council International. *Battery Service Manual, 11th ed.*, Chicago, IL: 1995.
- Chrysler Corp., *Basic Electricity: Student Reference Book.* 1989.
- Chrysler Corp., *Electricity and Electronics: Section 1— Fundamentals.*
- Crouse, William H. and Donald L. Anglin. *Automotive Mechanics, 9th ed.*, New York: McGraw-Hill Publishing Co., 1985.
- Denton, Tom. *Automobile Electrical &, Electronic Systems.* Warrendale, PA: SAE International, 1995.
- Duffy, James E. *Auto Electricity and Electronics Technology*, Tinley Park, IL: Goodheart-Willcox Company, Inc., 1998.
- Erjavec, Jack and Robert Scharff. *Automotive Technology—A Systems Approach*, Albany, NY: Delmar Publishers, 1992.
- General Motors. *Specialized Electronics Training (SET)*, 1995.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual,* 2nd ed., Albany, NY: Delmar Publishers, Inc., 1996.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual,* 2nd ed., Albany, NY: Delmar Publishers, Inc., 1996.
- Freightliner Corp., *Service Manual 00-98.* 1998.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems),* Albany, NY: Delmar Publishers, 2000.
- Norman, Ian, et al. *Heavy Duty Truck Systems,* 3rd ed. Albany, NY: Delmar Publishers, Inc., 2001.

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- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics, 1st ed.* Albany NY: Delmar Publishers, 2001.

Electronic Media

Video

- Unit 5: Electrical System (23 min.)

  Explains battery care, cleaning, visual inspection, electrolyte level check, and battery charging.

  Order the preceding video online from Nimco at www.nimcoinc.com, or call 800-962-6662.

Answers to Assignment Sheet

Assignment Sheet 1

Evaluate Factors in Selecting the Appropriate Battery for a Vehicle

1. C
2. No
3. D
4. B
5. D
6. A
7. D
8. B
9. C
10. D
11. No
12. D
13. B
14. No
15. Starting the engine
16. B
17. C
18. D
19. D
20. D

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms related to battery diagnosis and servicing to their correct definitions. Write the correct numbers in the blanks.

1. Aftermarket
2. Battery
3. Cell
4. Cold cranking amps
5. Electrolyte
6. Hydrometer
7. Reserve capacity rating
8. Short
9. Specific gravity
10. Sulfated

_____ a. Determines how much current a 12-volt battery can supply for 30 seconds at 0° F without dropping below 8.5 volts

_____ b. A test instrument for determining the specific gravity of electrolyte

_____ c. An unwanted electrical path that sometimes goes directly to the ground

_____ d. Weight of electrolyte compared to an equal volume of water at 60° F

_____ e. Two or more connected cells that convert chemical energy into electrical energy

_____ f. Indicates how many minutes a fully charged battery operating at 80° F can supply a current of 25 amps, before the battery voltage drops below 10.5 volts

_____ g. A product installed on a vehicle after it is manufactured

_____ h. Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

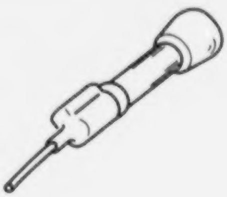
_____ i. One positive plate group and one negative plate group

_____ j. Solution of water and sulfuric acid

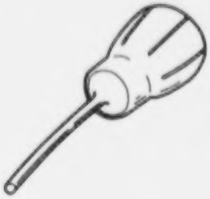
Written Test

Objective 2

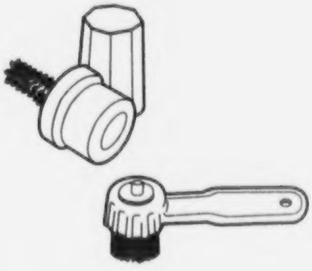
Label the following battery service tools used by diesel technicians. Write your answers in the blanks provided.



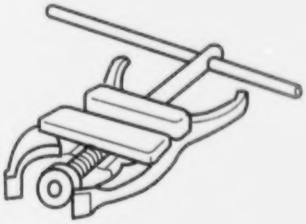
a. ____________________



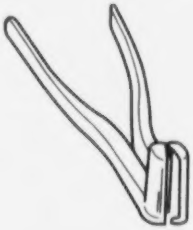
b. ____________________



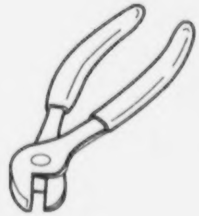
c. ____________________



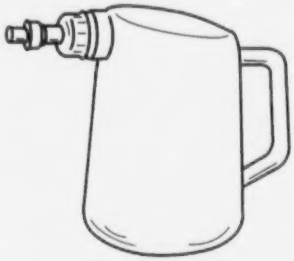
d. ____________________



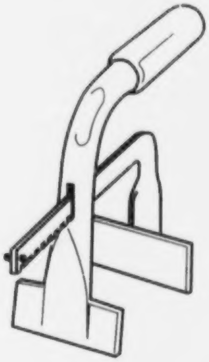
e. ____________________



f. ____________________



g. ____________________



h. ____________________

Written Test

Objective 3

List five functions of the battery.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

Objective 4

Match types of batteries to their descriptions.

1. Conventional battery
2. Maintenance-free battery

_____ a. Distilled water must be occasionally added to the battery through removable filler caps to keep the battery operating correctly.

_____ b. The most common type of battery, their special construction greatly reduces the need to add distilled water to keep the battery operating.

Objective 5

Match ratings of batteries to their descriptions.

1. Cold cranking amps (CCA)
2. Reserve capacity

_____ a. Indicates how may minutes a fully-charged battery operating at 80° F can supply a current of 25 amps before battery voltage drops below 10.5 volts.

_____ b. Indicates how much current (in amps) a 12-volt battery can supply for 30 seconds at 0° F without dropping below 8.5 volts.

Objective 6

List four factors affecting correct battery selection.

a. ____________________

____

b. ____________________

____

c. ____________________

____

d. ____________________

Written Test

Objective 7

List safety rules for working with batteries.

a. Wear—

b. mixture—

c. covers—

d. smoke—

e. live circuits—

f. disconnect, negative—

g. reconnect, positive—

h. rings and jewelry—

i. Unplug/turn off—

j. conductor—

k. frozen—

l. jumper cables—

Objective 8

Match types of battery connections to their correct system. Write the correct numbers in the blanks.

1. Series 2. Parallel 3. Series-Parallel

_____ a. A 12-volt system using 6-volt batteries

_____ b. A 24-volt system using 12-volt batteries

_____ c. A 12-volt system using 12-volt batteries

_____ d. A 24-volt system using 6-volt batteries

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 4
b. 6
c. 8
d. 9
e. 2
f. 7
g. 1
h. 10
i. 3
j. 5

Objective 2

a. Hydrometer
b. Syringe
c. Post cleaner
d. Clamp puller
e. Terminal spreader plier
f. Angle nose plier
g. Battery filler
h. Battery carrier

Objective 3

The answer should include all of the following in any order:

a. Stores electricity
b. Provides electricity to start the engine
c. Stabilizes voltage for the vehicle's electrical system
d. Provides electricity whenever the vehicle's electrical demands are greater than the charging system output
e. Provides electricity for vehicle accessories when the engine is not running or the charging system is not working

Objective 4

a. 1
b. 2

Objective 5

a. 2
b. 1

Objective 6

The answer should include all of the following in any order:

a. Manufacturer's recommended battery size
b. The physical features of the battery
c. Temperature of the climate in which the vehicle will operate
d. Electrical options added to the vehicle after purchase

Objective 7

The answer should include all of the following in any order:

a. Wear safety glass/face shield, rubber gloves, and a rubber apron when working with batteries.

b. Keep a mixture of baking soda and water nearby when working with batteries.

c. Use fender covers to protect the vehicle from accidental electrolyte spills.

d. Do not smoke near a battery that is being charged or near a battery that has been recently charged.

e. Do not break live circuits at the battery.

f. When disconnecting the battery, disconnect the negative cable first.

g. When reconnecting the battery, reconnect the positive cable first.

h. Remove metal rings and jewelry before working on the battery.

i. Unplug/turn off the battery charger before connecting or disconnecting it to the battery.

j. Never lay any conductor across the battery terminals.

k. Do not attempt to jump-start a battery that may be frozen.

l. When connecting jumper cables to a battery, connect the ground to the vehicle frame or engine as far as possible from the battery.

Objective 8

a. 3
b. 3
c. 2
d. 1

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1and 2.

☐ 4. **Read** Student Supplement 1, "How a Battery Works."

Optional

☐ 5. **Research** Online resources regarding general information on how batteries are made, what batteries do, and the different types of batteries. Visit www.batterycouncil.org as one of your resources.

☐ 6. **Study** Information Sheet, Objectives 3 through 7.

☐ 7. **Do** Assignment Sheet 1, "Evaluate Factors in Selecting the Appropriate Battery for a Vehicle."

☐ 8. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat Steps 6 and 7.

☐ 9. **Study** Information Sheet, Objective 8.

Optional

☐ 10. **View** Videotape entitled "Electrical System."

☐ 11. **Do** Job Sheet 1, "Maintain and Restore Electronic Memory Functions."

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 11.

☐ 13. **Do** Job Sheet 2, "Inspect, Clean, Fill, and Replace a Battery, Battery Cables, Connectors, Clamps, Battery Box, and Hold-Downs."

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 13.

☐ 15. **Do** Job Sheet 3, "Make a Battery State-of-Charge Test."

☐ 16. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 15.

☐ 17. **Do** Job Sheet 4, "Make a Battery Capacity (load) Test."

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 17.

☐ 19. **Do** Job Sheet 5, "Determine Battery State-of-Charge Using an Open Circuit Voltage Test."

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 19.

☐ 21. **Do** Job Sheet 6, "Slow and Fast Charge a Battery."

☐ 22. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 23. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 21.

☐ 23. **Do** Job Sheet 7, "Diagnose Parasitic (key-off) Battery Drain Problems."

☐ 24. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 23.

☐ 25. **Do** Job Sheet 8, "Connect Batteries in Series, Parallel, and Series-Parallel."

☐ 26. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 8 and repeat Step 25.

☐ 27. **Do** Job Sheet 9, "Jump-Start a Vehicle."

☐ 28. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 29. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 9 and repeat Step 27.

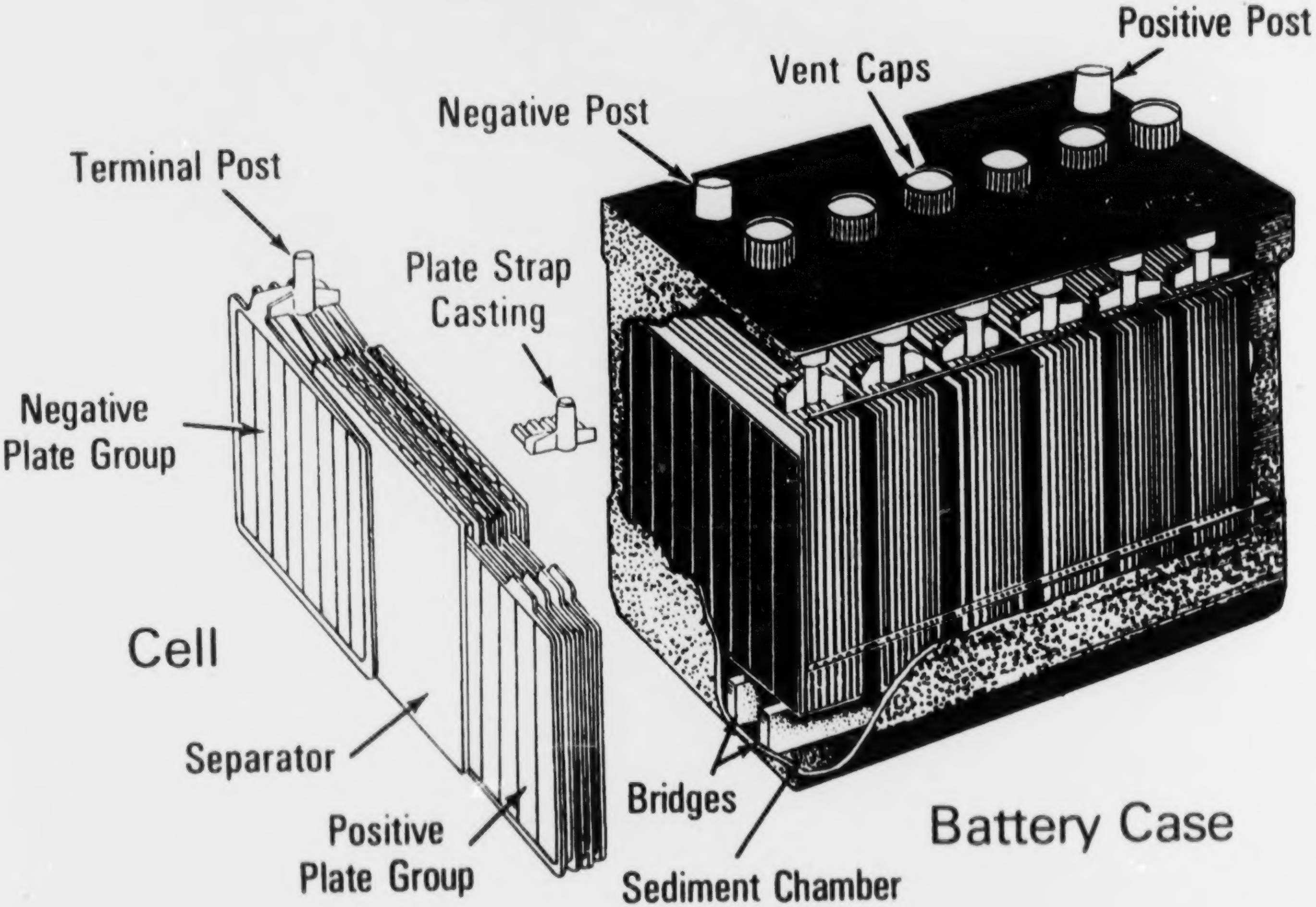
☐ 29. **Check** With instructor for any additional assignments to be completed.

☐ 30. **Take** Posttest provided by instructor. After the test has been evaluated, follow instructor's recommendations.

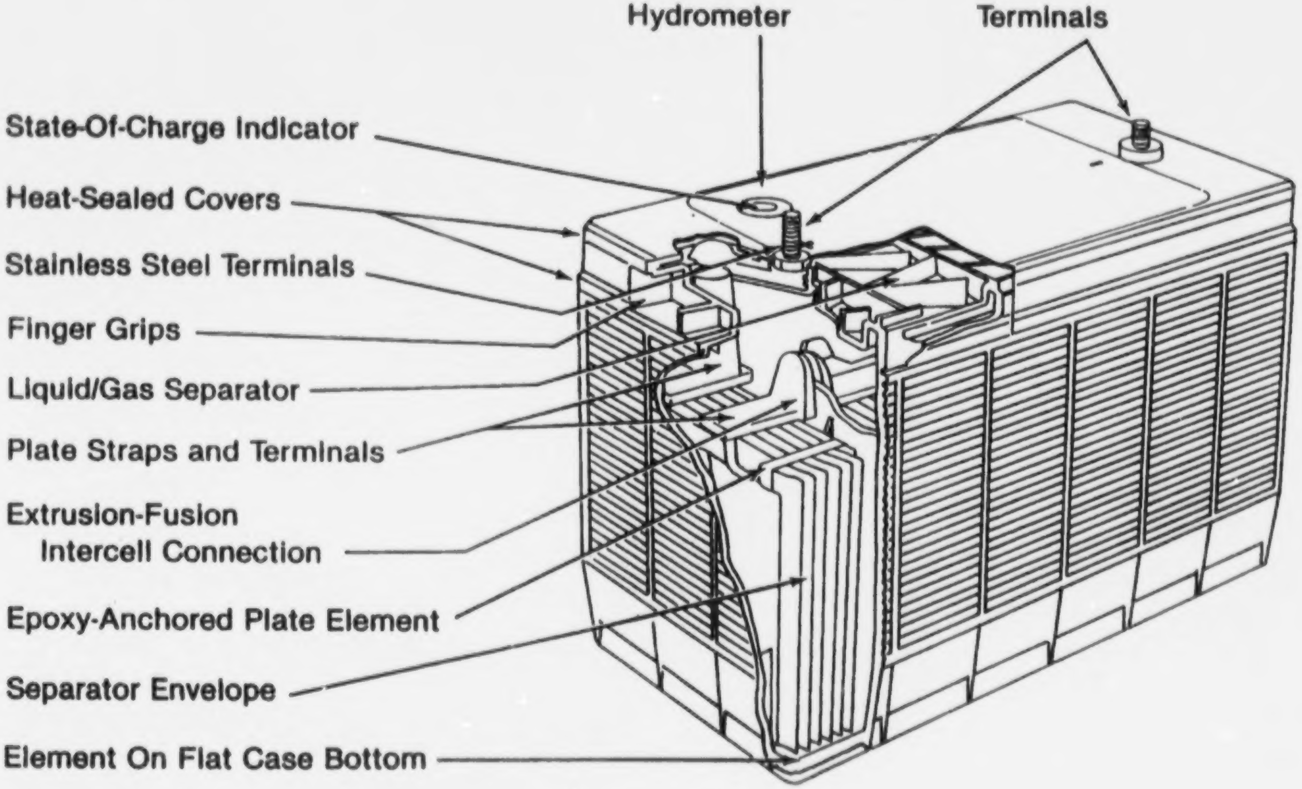
☐ 31. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next Learning Activities Sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Conventional Battery


Positive Post
Vent Caps
Negative Post
Terminal Post
Plate Strap Casting
Negative Plate Group
Cell
Separator
Positive Plate Group
Bridges
Sediment Chamber
Battery Case

Maintenance-Free Battery


Hydrometer
Terminals
State-Of-Charge Indicator
Heat-Sealed Covers
Stainless Steel Terminals
Finger Grips
Liquid/Gas Separator
Plate Straps and Terminals
Extrusion-Fusion Intercell Connection
Epoxy-Anchored Plate Element
Separator Envelope
Element On Flat Case Bottom

Unit 6 Starting Systems Diagnosis & Repair

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Student Page

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Parts of a Starting System (Objective 3)
TM 2—Parts of a Starting Motor (Objective 4)
TM 3—Components of an Armature (Objective 7)
TM 4—Starter Field Circuits (Objective 9)
TM 5—Types of Electromagnetic or Lever Shift Drives (Objective 13)
TM 6—Series-Parallel Switch–24 Volts (Objective 14)
TM 7—Series-Parallel Switch–12 Volts (Objective 14)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

Suggested Activities

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Show students different types of starters and explain the differences between them.
- Disassemble a starter to show the various parts and how they work together.
- Take a field trip to a starter rebuilding shop.
- Explain the different types of starting aids, and show students where and how each is used in the vehicle.
- Demonstrate how to connect test equipment for troubleshooting starter problems.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Classroom Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Shop Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Denton, Tom. *Automobile Electrical and Electronic Systems.* Warrendale, PA: SAE International, 1995.
- Derato, Frank C. *Automotive Electrical and Electronic Systems Shop Manual.* Glencoe/McGraw-Hill.

- Duffy, James E. *Auto Electricity and Electronics Technology*. Tinley Park, IL: Goodheart-Wilcox Co., 1998.
- Duffy, James E. *Auto Electricity, Electronics, Computers*. South Holland, IL: Goodheart-Wilcox Co., 1989.
- Duffy, James E. *Modern Automotive Mechanics*. South Holland, IL: Goodheart-Wilcox Co., 1985.
- Fowler, Richard J. *Electricity: Principles and Applications*. New York: Glencoe, 1994.
- Halderman, James D. *Automotive Electrical and Electronic Systems: A Worktext*. Englewood Cliffs, NJ: Prentice Hall, 1996.
- Halderman, James D. *Diagnosis and Troubleshooting of Automotive Electrical, Electronic, and Computer Systems*. Upper Saddle River, NJ: Prentice Hall, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual*. Albany, NY: Delmar Publishers, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual*. Albany, NY: Delmar Publishers, 1997.
- Johnson, Larry, and William King. *Automotive Encyclopedia*. Westerville, OH: Goodheart-Wilcox Co., 1983.
- Knowles, Don. Today's Technician: *Classroom Manual Automotive Computer Systems*. Albany, NY: Delmar Publishers, 1995.
- Mitchell International. *Domestic Cars Service and Repair 1991*. San Diego, CA: Mitchell International, 1991.
- Santini, Al. *Automotive Electricity and Electronics*. Albany, NY: Delmar Publishers, 1997.
- Santini, Al. *Automotive Electricity and Electronics: Instructor's Guide*. Albany, NY: Delmar Publishers, 1997.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*, 1st ed. Albany, NY: Delmar Publishers, 1999.

Suggested Activities

- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheet

Assignment Sheet 1

Diagnose Starting System Problems

1. All three of these are required:

   - weak or dead battery
   - corroded battery cable connections
   - damaged or worn components of the starting system

2. All three of these are required:

   - battery load test
   - state of charge test
   - cranking voltage test

3. Both of these are required:

   - starter current draw
   - circuit voltage drop

4. Four of these are required:

   - electrolyte level in the battery
   - loose or corroded battery terminal connections
   - dirt buildup on the battery top
   - battery hold-down connections, clamps, and tray
   - battery case and terminal cracks or other damage

5. C

6. Any three of the following answers is correct.

   - low or no engine oil level
   - oil pan damage
   - engine block damage
   - belt wear or damage
   - belt-driven part damage

7. Any three of the following answers is correct.

   - loose or corroded battery terminals
   - low electrolyte fluid
   - battery cables too small
   - worn or damaged battery cables

8. B

Answers to Assignment Sheet

9. C
10. B
11. C
12. B

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms related to starting systems diagnosis and repair to their definitions. Write the number of the correct answer in the blank.

1. Armature
2. Brushes
3. Cemf
4. Commutator
5. Field winding
6. Inertia
7. Motor switch
8. Pinion
9. Pole pieces
10. Solenoid
11. Starter switch

_____ a. Ends of a magnet in the field frame assembly of a starting motor

_____ b. Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings

_____ c. Main drive of starter motor; converts electrical energy into mechanical energy.

_____ d. Metal segments attached to ends of wire loops to form contact surface on armature

_____ e. Sliding contacts to feed electrical energy from battery to commutator

_____ f. Small gear that meshes with a larger gear

_____ g. Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

_____ h. Any switch that closes the circuit between the battery and starter motor

_____ i. Tendency of a body in motion to remain in motion

_____ j. Counter electromotive force

_____ k. Activates the motor switch

Written Test

Objective 2

Select from the following list, types of starting aids by placing an "X" in the blank beside each correct type.

_____ a. Oil heater

_____ b. Block heater

_____ c. Clutch

_____ d. Glow plugs/intake heater

_____ e. Starter switch

_____ f. Starting fluid

_____ g. Fuel heater

Objective 3

Match the terms related to the parts of a starting system to their definitions. Write the number of the correct answer in the blank.

1. Battery
2. Cable and wiring
3. Ignition switch (key switch)
4. Starter motor
5. Starter safety switch
6. Starter relay/solenoid

_____ a. Allows current to flow from the battery through the solenoid to the starting motor

_____ b. Controls starting system operation by closing or opening the circuit to the starter relay or solenoid

_____ c. Converts electrical energy from the battery into mechanical energy

_____ d. Prevents the engine from cranking unless the shift selector is in neutral or park on an automatic transmission or if the clutch is depressed on a manual transmission

_____ e. Carries current to the components of the starting system

_____ f. Stores and provides energy to the starting system

Objective 4

Select the major parts of a starting motor by placing an "X" in the blank beside the correct part.

_____ a. Motor switch

_____ b. Pole shoe

_____ c. Field frame assembly

_____ d. Armature

_____ e. Rotor

_____ f. Drive mechanism

Objective 5

Match the terms related to the component parts of a starting system to their definitions. Write the number of the correct answers in the blanks.

1. Armature
2. Brushes
3. Commutator
4. Field winding
5. Pole shoe

_____ a. Forms a magnetic field of force around armature

____ b. Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding

____ c. Converts electrical energy into mechanical energy to drive mechanism to crank engine

____ d. Forms contact surface for battery to feed electrical current through armature

____ e. Sliding contacts which feed electrical energy to the commutator

Objective 6

Arrange the steps in a starting system in the order in which they occur. Write the correct sequence number (1-5) on each line.

_____ a. The current travels through the field coils, brushes, and commutator of the armature of the starter motor causing the armature to spin.

____ b. The starter relay closes the solenoid contacts allowing high current to flow from the battery cables through the solenoid to the starter.

____ c. As the flywheel turns, it spins the crankshaft fast enough to build compression heat to ignite the injected fuel entering the cylinders and start the engine.

____ d. Current passes from the battery, through the ignition switch, and in some cases, through the safety switches, then to the starter relay.

____ e. The spinning armature shaft of the starter motor turns the pinion drive gear moving the flywheel by contacting the ring gear portion of the flywheel.

Objective 7

Complete the following statement concerning the conversion of electrical energy into mechanical energy by filling in the blanks correctly with the following words: rotate, conductor, magnetic.

Current carrying ________________ formed in a loop and mounted on a shaft, will cause the shaft to ________________ when placed inside a ________________ field.

Written Test

Objective 8

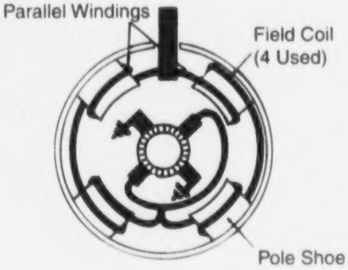
Select true statements concerning how a starting motor is kept running by placing an "X" beside each statement that is true.

_____ a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

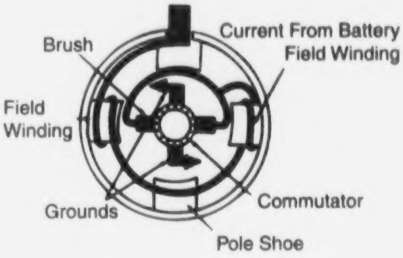
_____ b. Metal segments on the ends of the commutator make one-half turn reversing their connection through sliding contacts which causes the current to flow in the opposite direction in the armature windings.

Objective 9

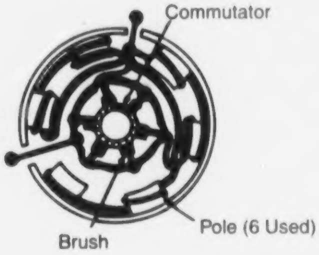
Identify four types of starter field circuits. Write your answers in the blanks.


Parallel Windings
Field Coil (4 Used)
Pole Shoe

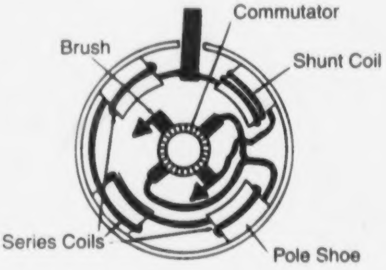
a. ______________________


Brush
Current From Battery
Field Winding
Field Winding
Grounds
Commutator
Pole Shoe

b. ______________________


Commutator
Pole (6 Used)
Brush

c. ______________________


Commutator
Brush
Shunt Coil
Series Coils
Pole Shoe

d. ______________________

Objective 10

Match the types of starter field circuits with the current flow in each type circuit. Write the number of the correct answer in the blank.

1. Compound-wound
2. Parallel-wound
3. Series-parallel-wound
4. Series-wound

_____ a. Current flows through all field windings before it flows through the two insulated brushes in the armature.

_____ b. Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.

_____ c. One-third of the current flows through each pair of field windings to one of the three insulated brushes.

_____ d. One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.

Objective 11

List four types of starting motor switches. Write your answers in the blanks.

____

____

____

____

Objective 12

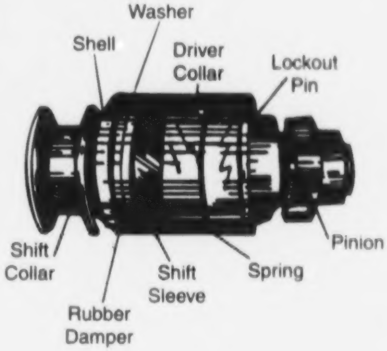
Explain two ways starter drives are engaged. Write your answers in the blanks.

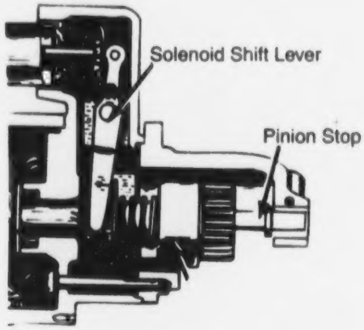
a. ______________________________

b. ______________________________

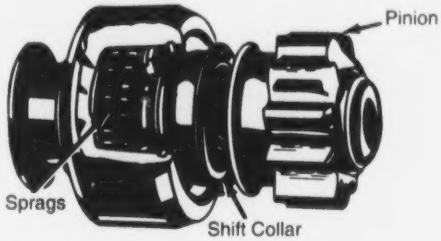
Objective 13

Identify three types of electromagnetic or lever shift drives. Write your answers in the blanks.


Washer
Shell
Driver Collar
Lockout Pin
Pinion
Spring
Shift Sleeve
Shift Collar
Rubber Damper


Solenoid Shift Lever
Pinion Stop

a. ______________________ b. ______________________


Pinion
Sprags
Shift Collar

c. ______________________

Objective 14

Arrange the steps in the operation of a series-parallel switch in the order in which they occur. Write the correct sequence number (1-3) on each line.

_____ a. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over.

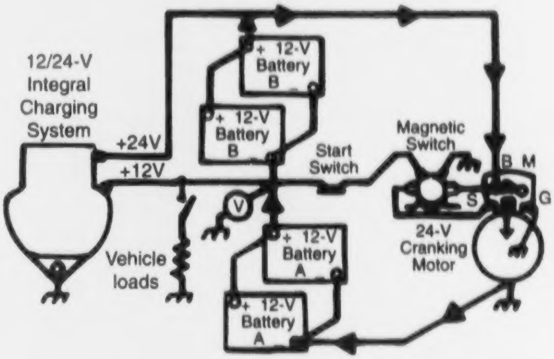
_____ b. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.

_____ c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation.

Objective 15

Arrange the steps in the operation of a transformer-rectifier unit in the order in which they occur. Write the correct sequence number (1-3) on each line.

_____ a. This action energizes the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative post of the batteries marked "A". This action connects both sets of batteries in series, creating 24 V for starting.


12/24-V
Integral
Charging
System
+24V
+12V
+ 12-V Battery B
+ 12-V Battery B
Start Switch
Magnetic Switch
B
M
S
G
V
+ 12-V Battery A
+ 12-V Battery A
24-V Cranking Motor
Vehicle loads

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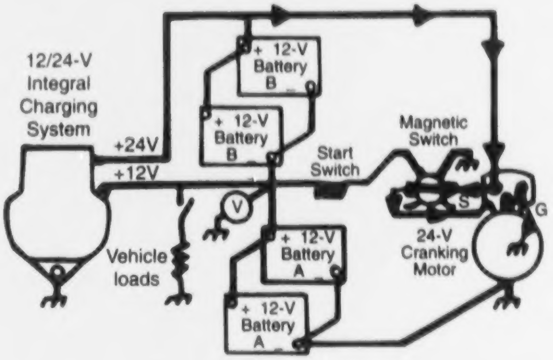
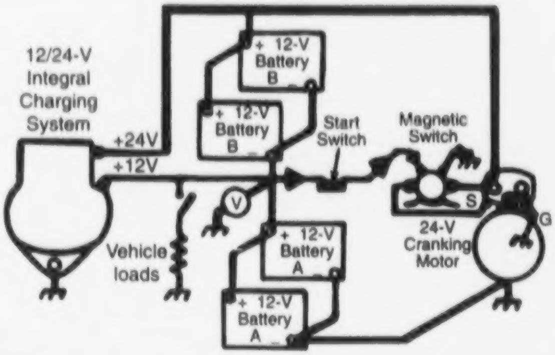
_____ b. The current for the solenoid switch and for cranking flows from the positive posts of the "B" batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.


12/24-V
Integral
Charging
System
+24V
+12V
+ 12-V Battery B
+ 12-V Battery B
Start Switch
Magnetic Switch
S
G
V
+ 12-V Battery A
+ 12-V Battery A
24-V Cranking Motor
Vehicle loads

Reprinted with permission of Delco Remy Division, GM Group.

_____ c. The operator closes the start switch, forcing 12 V from the batteries marked "A" through the magnetic switch, closing the cranking motor actuating circuit.


12/24-V Integral Charging System
+24V
+12V
+ 12-V Battery B –
+ 12-V Battery B –
Start Switch
Magnetic Switch
S
G
V
Vehicle loads
+ 12-V Battery A –
+ 12-V Battery A –
24-V Cranking Motor

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Objective 16

Match the starting system tests with their correct descriptions. Write the number of the correct answer in the blank.

1. Cranking voltage test
2. Current draw test
3. Starting headlight test
4. State-of charge test
5. Voltage drop test

_____ a. Locates higher than normal resistance across a cable, connection, or components such as the starter motor, starting safety switch, or solenoid.

_____ b. Tests the battery and starter motor by measuring battery voltage and current flow out of the battery; the test may indicate a problem in the battery or starter motor.

_____ c. Checks the voltage level of the battery charge in batteries that do not have a charge indicator.

_____ d. Measures the amount of voltage available from the battery for ignition while the engine is being cranks.

_____ e. Quickly diagnoses a weak or dead battery or a short in the cables or wiring, starter motor, solenoid, starting safety switch, or ignition switch.

Objective 17

Describe how types of starting system test equipment are connected to a vehicle. Write your answers on the bank lines provided.

12-volt test light

ammeter

hydrometer

inductive amp tester

load tester

ohmmeter

voltmeter

***Permission to duplicate this test is granted.**

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Answers to Written Test

Objective 1

a. 9
b. 5
c. 1
d. 4
e. 2
f. 8
g. 10
h. 7
i. 6
j. 3
k. 11

Objective 2

The correct order is:

a, b, d, f, g

Objective 3

a. 6
b. 3
c. 4
d. 5
e. 2
f. 1

Objective 4

a, c, d, f

Objective 5

a. 5
b. 4
c. 1
d. 3
e. 2

Objective 6

a. 3
b. 2
c. 5
d. 1
e. 4

Objective 7

conductor, rotate, magnetic

Objective 8

a, b

Answers to Written Test

Objective 9

a. Parallel-wound
b. Series-wound
c. Series-parallel-wound
d. Compound wound

Objective 10

a. 4
b. 2
c. 3
d. 1

Objective 11

Answers should include all the following in any order:

- Manual
- Solenoid
- Magnetic
- Series-Parallel

Objective 12

Answers should include both the following in any order:

- Inertia or armature acting through drive mechanism
- Electromagnetic plunger to mechanically shift pinion into mesh

Objective 13

a. Positork®
b. Overrunning clutch
c. Sprag clutch drive

Objective 14

a. 2
b. 1
c. 3

Objective 15

a. 3
b. 2
c. 1

Objective 16

a. 4
b. 2
c. 5
d. 3
e. 1

Objective 17

- **12-volt test light**—The probe should be placed on the switch output wire connection while testing switches, or refer to wiring diagram for test points on relay/solenoid or other components.
- **ammeter**—The probe is placed in the test circuit on series between the power source and the load.
- **hydrometer**—The rubber tube or stick end of the hydrometer is placed into the electrolyte fluid inside the battery.
- **inductive amp tester**—The clamp is clamped around the negative battery cable with the arrow pointing away from the battery.
- **load tester**—The leads are connected to the positive and negative battery terminals.
- **ohmmeter**—The probe is placed on either side of the wire or component being tested.
- **voltmeter**—The probe is placed in the test circuit on either side of the load being tested.

Prerequisites:
None

Learning Activities Sheet

Student Name ____________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 15.

☐ 4. **Read** Student Supplement 1, "Starting System Diagnosis Chart".

☐ 5. **Do** Assignment Sheet 1, "Diagnosing Starting System Problems".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat Steps 3, 4, and 5.

☐ 7. **Study** Information Sheet, Objectives 16 and 17.

☐ 8. **Do** Job Sheet 1, "Make a No-Load Starter Current Draw Test".

☐ 9. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and and repeat Step 8.

☐ 10. **Do** Job Sheet 2, "Make Starter Circuit Voltage Drop Tests".

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and and repeat Step 10.

Learning Activities Sheet

☐ 12. **Do** Job Sheet 3, "Inspect, Test, and Repair or Replace Switches, Connectors, and Wires of Starter Control Circuits".

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and and repeat Step 12.

☐ 14. **Do** Job Sheet 4, "Inspect, Test, and Replace Starter Relays and Solenoids".

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and and repeat Step 14.

☐ 16. **Do** Job Sheet 5, "Remove and Replace Starter".

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and and repeat Step 16.

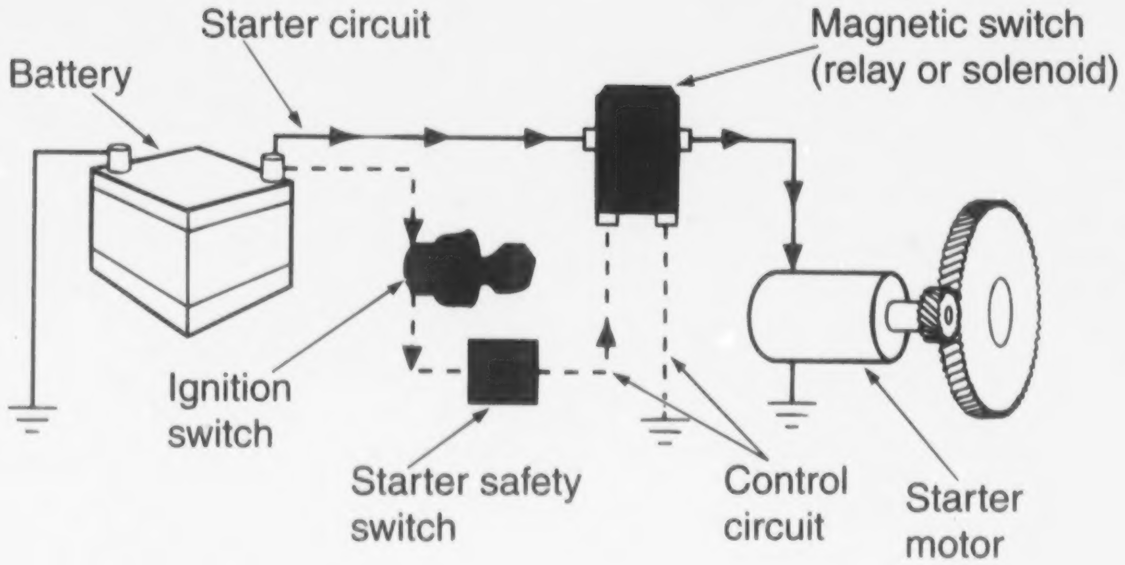
☐ 18. **Check** With instructor for any additional assignments to be completed.

☐ 19. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

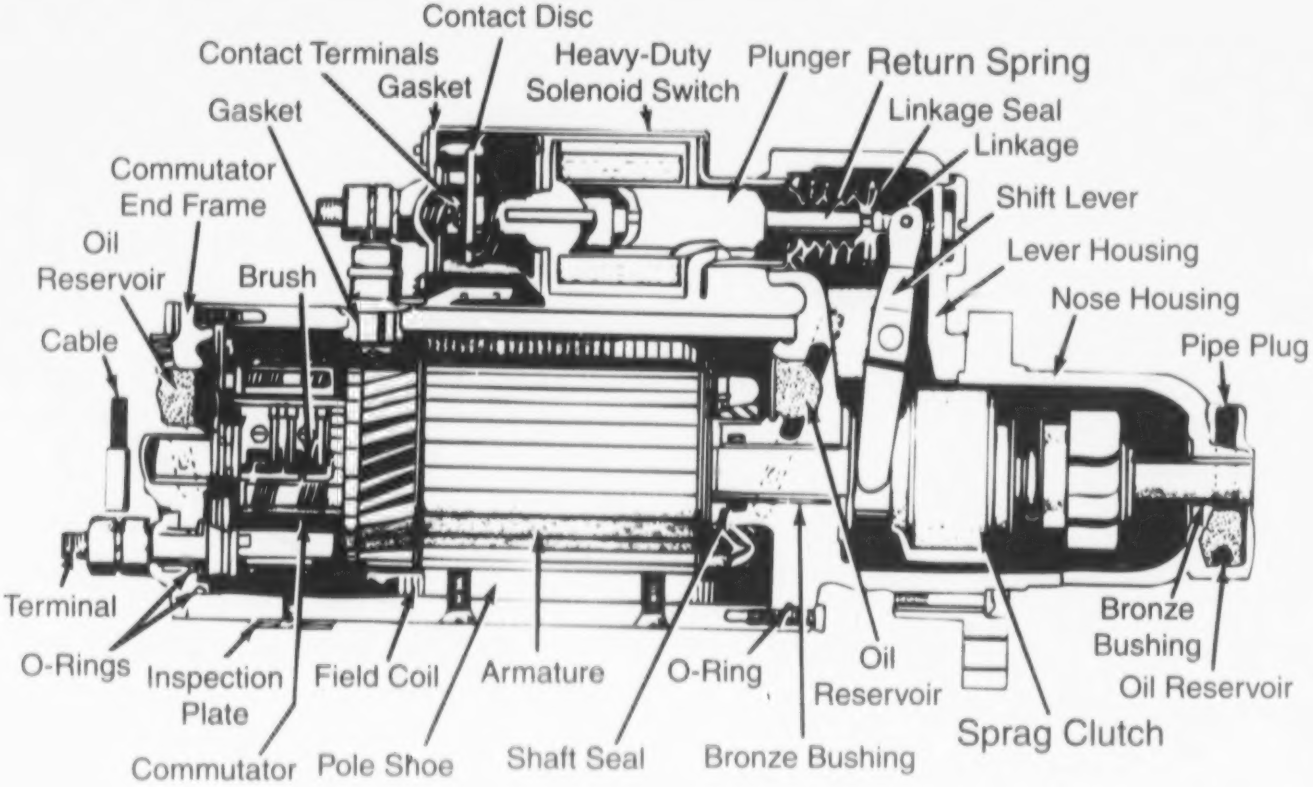
☐ 20. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

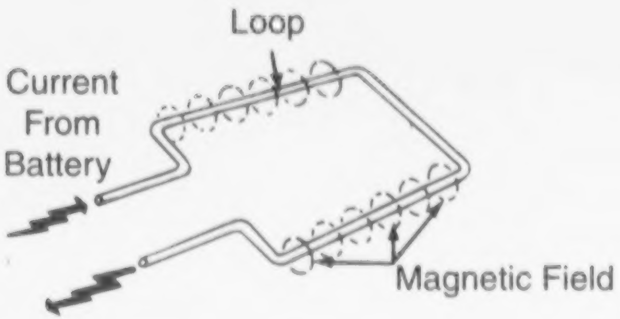
Parts of a Starting System


Starter circuit
Magnetic switch
(relay or solenoid)
Battery
Ignition
switch
Starter safety
switch
Control
circuit
Starter
motor

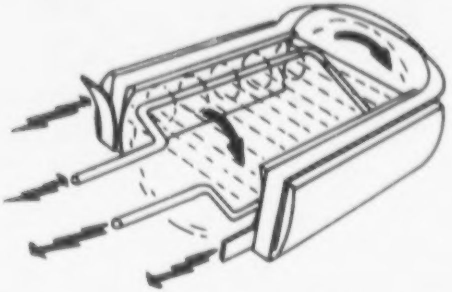
Parts of a Starting Motor


Contact Disc
Contact Terminals
Gasket
Heavy-Duty Solenoid Switch
Plunger
Return Spring
Linkage Seal
Linkage
Gasket
Commutator End Frame
Shift Lever
Lever Housing
Oil Reservoir
Brush
Nose Housing
Cable
Pipe Plug
Terminal
O-Rings
Inspection Plate
Field Coil
Armature
O-Ring
Oil Reservoir
Bronze Bushing
Oil Reservoir
Sprag Clutch
Commutator
Pole Shoe
Shaft Seal
Bronze Bushing

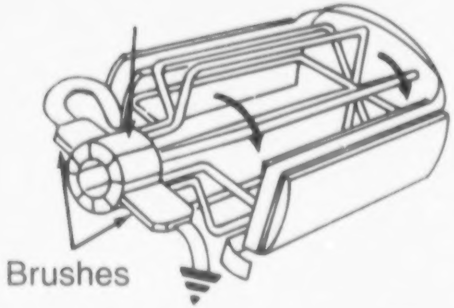
Components of an Armature


Loop
Current
From
Battery
Magnetic Field

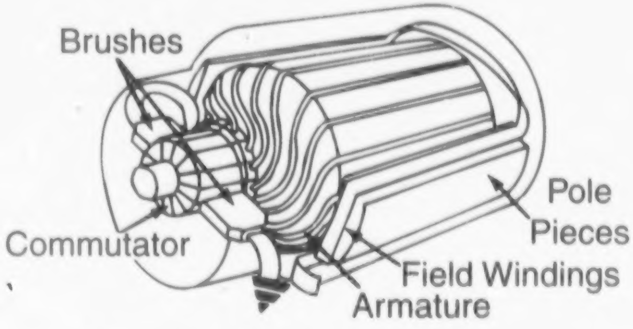
Loop of "Live" Wire and Its Magnetic Field



Loop Placed In Field Windings

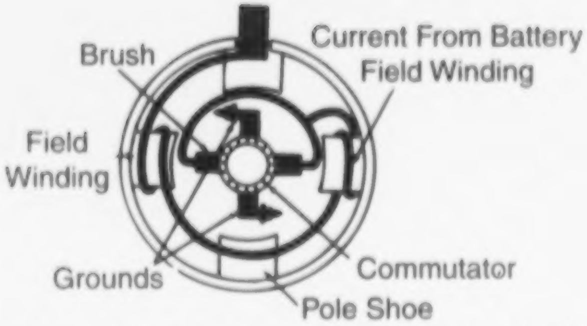


Armature for Starting Motor

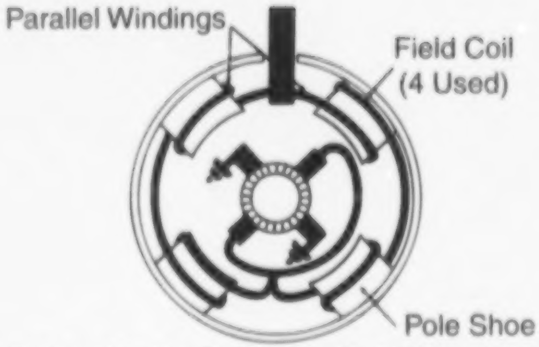

Brushes
Commutator
Pole
Pieces
Field Windings
Armature

Armature and Brushes

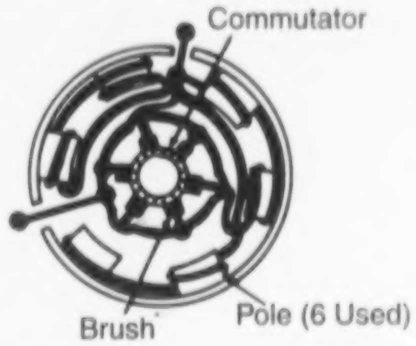
Starter Field Circuits


Brush
Current From Battery
Field Winding
Field
Winding
Grounds
Commutator
Pole Shoe

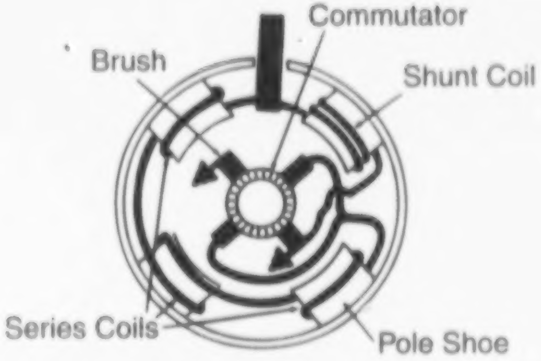
Four-Pole—Two-Coil Series-Wound Motor


Parallel Windings
Field Coil
(4 Used)
Pole Shoe

Four-Pole—Four-Coil Parallel-Wound Motor

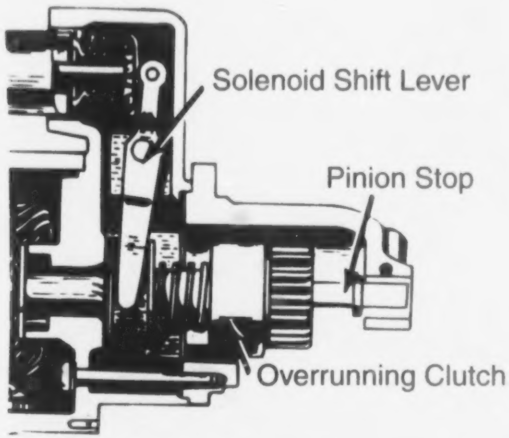

Commutator
Brush
Pole (6 Used)

Six-Pole—Six-Coil Series-Parallel-Wound Motor

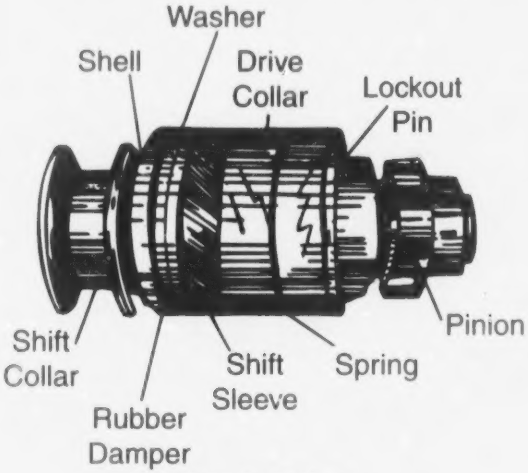

Commutator
Brush
Shunt Coil
Series Coils
Pole Shoe

Compound-Wound Motor.

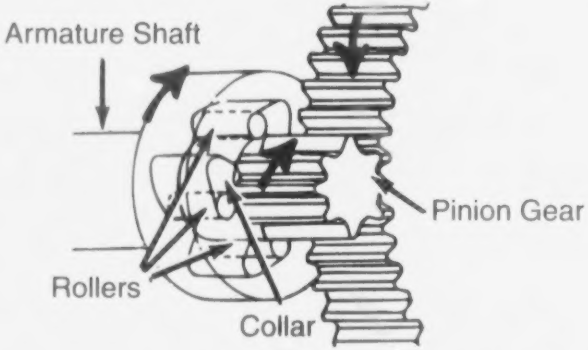
Types of Electromagnetic or Lever Shift Drives


Solenoid Shift Lever
Pinion Stop
Overrunning Clutch

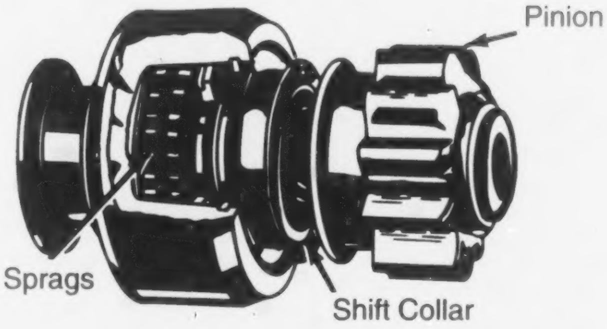
Overrunning Clutch


Washer
Shell
Drive Collar
Lockout Pin
Pinion
Spring
Shift Sleeve
Shift Collar
Rubber Damper

Positork Drive

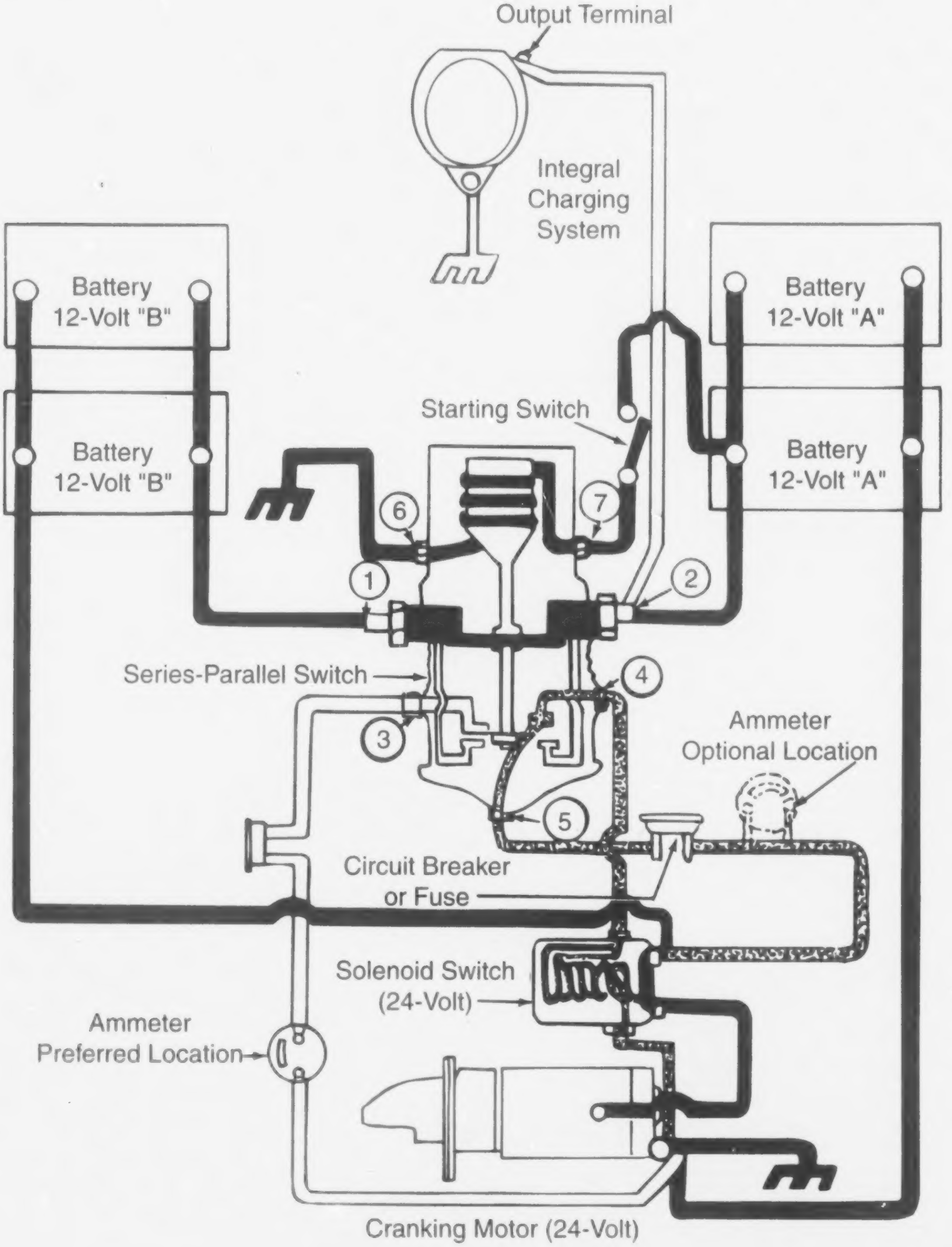

Armature Shaft
Pinion Gear
Rollers
Collar

Overrunning Clutch Drive Engaged

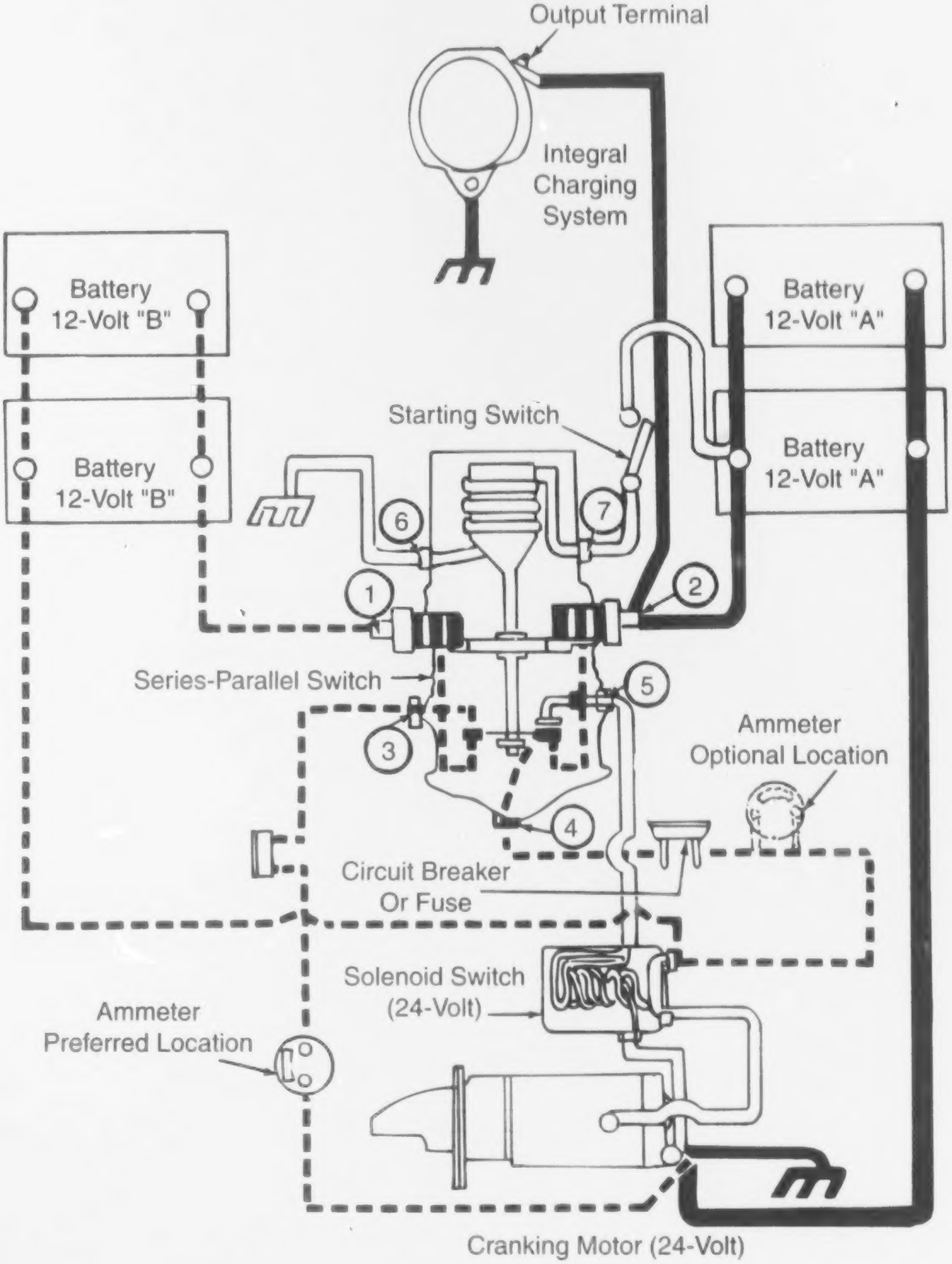

Pinion
Sprags
Shift Collar

Sprag Clutch Drive

Series-Parallel Switch—24 Volts


Output Terminal
Integral Charging System
Battery 12-Volt "B"
Battery 12-Volt "B"
Battery 12-Volt "A"
Battery 12-Volt "A"
Starting Switch
6
7
1
2
Series-Parallel Switch
4
3
Ammeter Optional Location
5
Circuit Breaker or Fuse
Solenoid Switch (24-Volt)
Ammeter Preferred Location
Cranking Motor (24-Volt)

Series-Parallel Switch—12 Volts


Output Terminal
Integral Charging System
Battery 12-Volt "B"
Battery 12-Volt "B"
Battery 12-Volt "A"
Battery 12-Volt "A"
Starting Switch
6
7
1
2
Series-Parallel Switch
3
5
4
Ammeter Optional Location
Circuit Breaker Or Fuse
Solenoid Switch (24-Volt)
Ammeter Preferred Location
Cranking Motor (24-Volt)

TM 7

Unit 7 Charging Systems Diagnosis & Repair

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1—Diagnose Charging System Problems That Cause an Undercharge, a No-Charge, or an Overcharge Condition 7–13

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Parts of an Alternator (Objective 4)
  TM 2—Parts of an Alternator (continued) (Objective 4)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss the assignment sheet. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Show students where the parts of a charging circuit are located on a vehicle.
- Obtain a cut-a-way or disassembled alternator and show students the various parts and explain how each part operates.
- Show students examples of alternators with internal and external regulators.
- Explain how to identify a voltage regulator on a circuit diagram and trace a regulating circuit.
- On a circuit diagram, show students how to trace and identify an insulated group and charging systems circuit.
- Discuss with students the different charging system tests and when each one should be used.
- Show students how to connect charging system test equipment.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheet. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheet for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Derato, Frank C. *Automotive Electrical and Electronic Systems Shop Manual.* Glencoe/McGraw-Hill, 1990.
- Duffy, James E. *Auto Electricity, Electronics, Computers.* South Holland, IL.: Goodheart-Willcox Co., 1989.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual.* Albany, New York: Delmar Publishers, 1997.

- Hollembeak, Barry. *Today's Technician: Shop Manual for Automotive Electricity and Electronics.* Albany, New York: Delmar Publishers, 1994.
- Knowles, Don. *Today's Technician: Classroom Manual Automotive Computer Systems.* Albany, New York: Delmar Publishers, 1995.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Hollembeak, Barry. *Automotive Electricity, Electronics and Computer Controls*, 1st ed. Albany, NY: Delmar Publishers, 1999.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheet

Assignment Sheet 1

Diagnose Charging System Problems That Cause an Undercharge, a No-Charge, or an Overcharge Condition

1. C
2. D
3. A
4. B
5. D
6. D
7. B
8. D
9. D
10. B

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to charging systems diagnosis and repair to their definitions. Write the number of the correct answer in the blank.

1. Brushless alternator
2. Heat sink
3. Open circuit
4. Rectifier bridge
5. Rotor
6. Slip rings
7. Stator
8. Transistorized regulator

_____ a. Circuit in which a wire is broken or disconnected

_____ b. Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

_____ c. Six diodes mounted in one assembly

_____ d. Laminated soft iron ring with three groups of coils

_____ e. Dissipates heat from diodes

_____ f. Wire coil wrapped around an iron core and mounted on a rotating shaft

_____ g. Fully electronic unit composed of resistors, diodes, zener diodes, transistors, and thermistor

_____ h. An alternator that has neither slip rings nor brushes

Objective 2

State the purpose of a charging system, an alternator, and charging system output tests.

1. State the purpose of a charging system. Write your answer on the blank lines.

____

____

2. State the purpose of an alternator. Write your answer on the blank lines.

____

____

3. State the purpose of charging system output tests. Write your answer on the blank lines.

____

____

____

Objective 3

Match alternator charging circuit components with their correct functions. Write your answers in the blanks.

1. Alternator
2. Ammeter
3. Battery
4. Indicator lights
5. Regulator
6. Voltmeter

____ a. Supplies current to crank the engine; helps out during peak operation when electrical load is too much for alternator, and stabilizes system voltage

____ b. Measures the rate of current flow

____ c. Supplies electrical power to accessory circuits and recharges battery

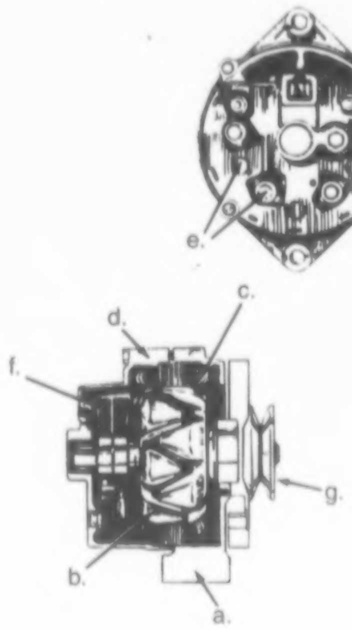
____ d. Indicates produced voltage

____ e. Limits the alternator voltage to a safe, preset value

____ f. Indicates problems in system; used in place of a meter

Objective 4

Identify the major parts of an alternator. Write your answers in the blanks.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

Objective 5

Describe how stator windings are constructed. Write your answer in the blanks.

____

____

____

Objective 6

Distinguish between types of alternator circuits by placing an "E" next to the description of an external regulator.

_____ a. Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a "B" circuit.

_____ b. Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an "A" circuit.

Written Test

Objective 7

Select from the following list, characteristics of a brushless alternator by placing an "X" beside each correct characteristic.

____ a. Is a low mileage unit

____ b. Is used on diesel engines only

____ c. Regulator compartment is non-vented

____ d. Uses large bushings at both ends

____ e. Has extra large grease reservoirs

____ f. Has extra small lip seal to keep grease in, and dirt out

____ g. Regulator compartment is air tight

____ h. Designed to operate between engine overhauls without attention.

Objective 8

Select true statements concerning operation of a brushless alternator by placing an "X" beside each statement that is true.

____ a. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.

____ b. The field coil is mounted to the end frame.

____ c. The rotor is mounted on bearings and fits between the stator and field coil.

____ d. The field coil produces a south pole at the right hand side of the coil.

____ e. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.

____ f. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand, south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.

____ g. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, DC voltage is generated in the stator windings.

Objective 9

Select true statements concerning operation of a transistorized regulator by placing an "X" beside each statement that is true.

_____ a. Allows battery current to excite the alternator field coils

_____ b. Controls charging voltage at safe values during operation by requesting the field current

Objective 10

Complete statements concerning safety rules for working with alternator charging circuits by circling the correct answer(s).

a. Never attempt to (**polarize, ground**) the circuit.

b. Be sure the battery is in good operating condition before making any tests or (**repairs, adjustments**).

c. Never operate the alternator in (**a closed, an open**) circuit, except when instructed in the technical manual.

d. Never (**short, disconnect**) or ground the alternator terminals.

e. Do not disconnect the voltage regulator while the alternator is (**running, grounded**).

f. Disconnect the (**positive, negative**) battery cable first when removing the alternator or battery.

g. Do not use (**acid-, rosin-**) core solder on the alternator terminals; use only a (**acid-, rosin-**) core solder.

h. Never immerse the circuit components in (**any, cleaning**) solution.

Objective 11

Match the names of charging system tests with descriptions of the conditions evaluated by the tests. Write the number of the correct answer in the blank. Definitions continue on the next page.

1. Battery high-rate discharge test
2. Circuit voltage drop test
3. Alternator output test
4. Regulator bypass test
5. Regulator voltage test
6. State-of-charge test

_____ a. Checks the calibration of the voltage regulator and detects a high or low voltage setting

_____ b. Measures the lowest point to which the battery voltage drops while the battery is discharging at a high rate

_____ c. Checks the voltage level of the battery charge in batteries that do not have a charge indicator

____ d. Locates higher than normal resistance across a cable, component, or connection during current flow

____ e. Measures the current and voltage output of the charging system leaving the regulator out of the circuit

____ f. Measures the maximum current the generator can produce at a specified voltage or maximum load

Objective 12

Describe how charging system test equipment is connected to the vehicle. Write your answers in the blank lines provided after the name of the test equipment.

a. **ammeter** — ____

____

b. **belt tension gauge** — ____

____

c. **hydrometer** — ____

____

d. **inductive amp tester** — _____________________________________

____

e. **load tester** — ____

____

f. **ohmmeter** — ____

____

g. **voltmeter** — ____

____

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a.	3	e.	2
b.	6	f.	5
c.	4	g.	8
c.	7	h.	1

Objective 2

1. The purpose of the charging system is to restore the battery's electrical charge and supply electricity to the electrical accessories.

2. The purpose of an alternator is to convert mechanical energy from the operation of the engine into the electrical energy required to restore the electrical charge of the battery.

3. The purpose of charging system output tests is to measure system current and voltage under maximum load.

Objective 3

a.	3	d.	6
b.	2	e.	5
c.	1	f.	4

Objective 4

a. Drive and frame
b. Rotor assembly
c. Stator assembly
d. Slip ring end frame
e. Diodes
f. Brush assembly
g. Pulley

Objective 5

Windings have three phases which are connected together to form a "Y" or delta connection, with each winding connected to a positive and negative diode.

Objective 6

a

Objective 7

e, g, h

Objective 8

a, b, c, e, f

Answers to Written Test

Objective 9

a, b

Objective 10

a. Polarize
b. Adjustments
c. Open
d. Short
e. Running
f. Negative
g. Acid-, Rosin-
h. Cleaning

Objective 11

a. 5
b. 1
c. 6
d. 2
e. 4
f. 3

Objective 12

1. **ammeter**—The probes are placed in the test circuit in series between the power source and the load.

2. **belt tension gauge**—Clamp the gauge onto the belt and read the gauge to measure the tension placed on the drive belt.

3. **hydrometer**—The rubber tube or stick end is placed into the electrolyte fluid inside the battery.

4. **inductive amp gauge**—The clamp is usually clamped around the positive battery cable with the arrow pointing in the direction of current travel.

5. **load tester**—The leads are connected to the positive and negative battery terminals.

6. **ohmmeter**—After the wire or component being tested has been disconnected from a source of voltage, the probes are placed on either side of the wire or component being tested.

7. **voltmeter**—The probes are placed in the test circuit on either side of the load being tested.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 12.

☐ 4. **Read** Student Supplement 1, "Charging System Diagnosis Chart".

☐ 5. **Do** Assignment Sheet 1, "Diagnose Charging System Problems That Cause an Undercharge, a No-Charge, or an Overcharge Condition".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat Steps 4 and 5.

☐ 7. **Do** Job Sheet 1, "Inspect, Adjust, and Replace Alternator Drive Belts, Pulleys, and Tensioners".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 7.

☐ 9. **Do** Job Sheet 2, "Make a Charging System Output Test; Determine Needed Repairs".

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 9.

Learning Activities Sheet

☐ 11. **Do** Job Sheet 3, "Make a Charging Circuit Voltage Drop Test; Determine Needed Repairs.".

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 11.

☐ 13. **Do** Job Sheet 4, "Test an S.I. Series Alternator".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 13.

☐ 15. **Do** Job Sheet 5, "Inspect, Repair, or Replace Connectors and Wires".

☐ 16. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 15.

☐ 17. **Do** Job Sheet 6, "Remove, Inspect, and Replace an Alternator".

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 17.

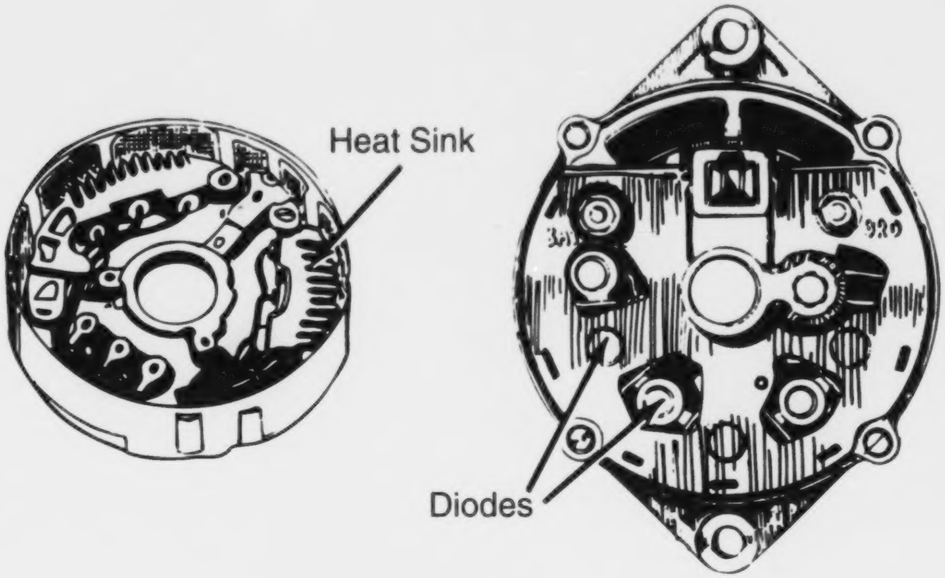
☐ 19. **Check** With instructor for any additional assignments to be completed.

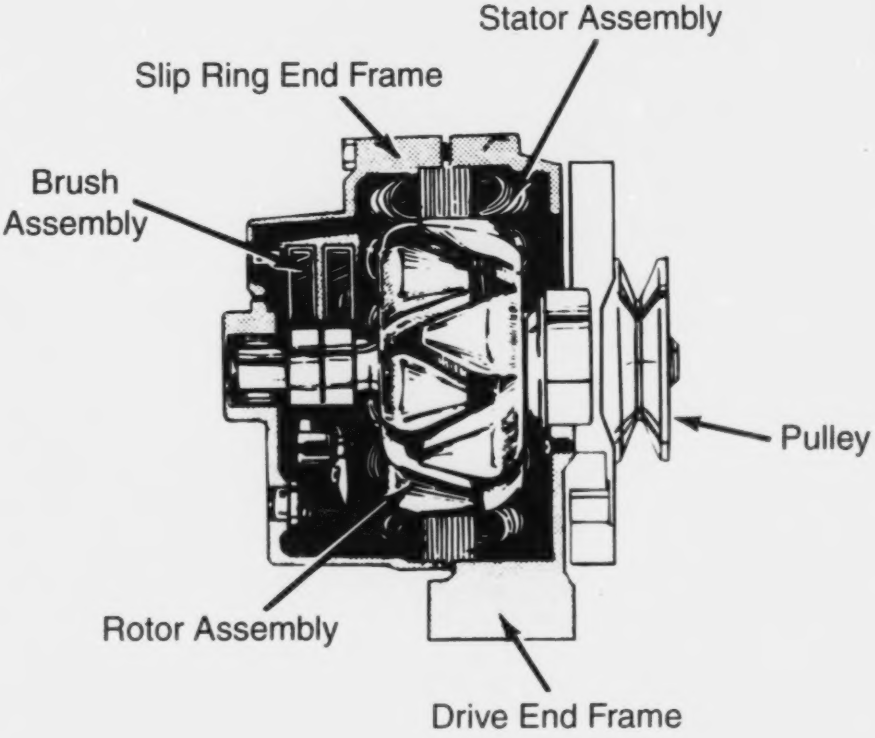
☐ 20. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 21. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

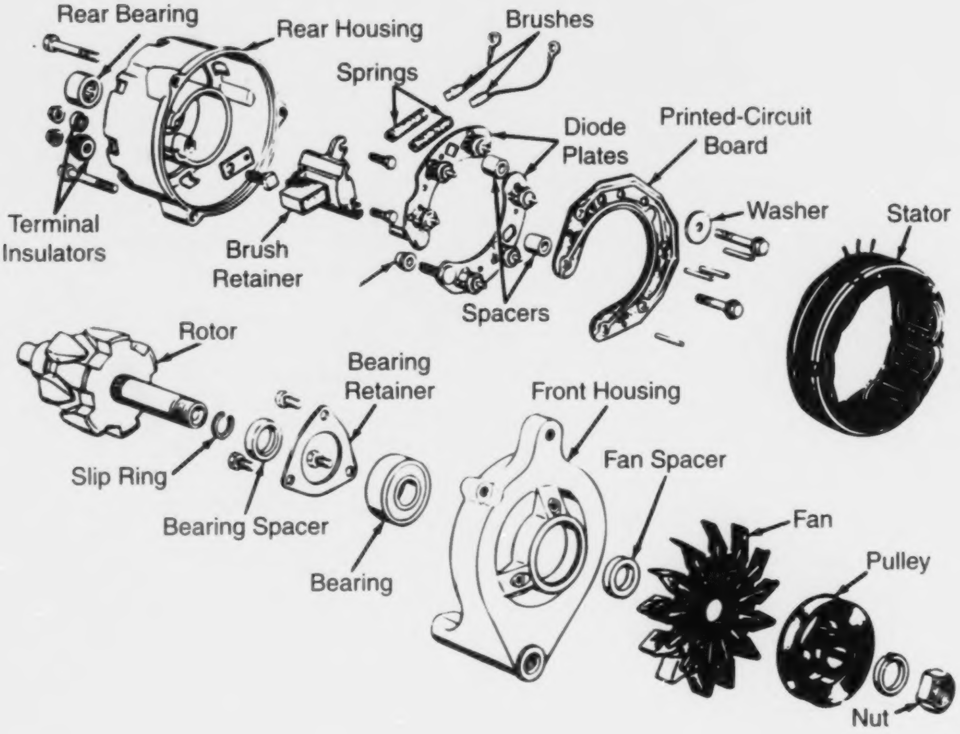
Parts of an Alternator


Heat Sink
Diodes


Stator Assembly
Slip Ring End Frame
Brush Assembly
Pulley
Rotor Assembly
Drive End Frame

Parts of an Alternator

(Continued)


Rear Bearing
Rear Housing
Brushes
Springs
Diode Plates
Printed-Circuit Board
Washer
Stator
Terminal Insulators
Brush Retainer
Spacers
Rotor
Bearing Retainer
Front Housing
Fan Spacer
Fan
Pulley
Slip Ring
Bearing Spacer
Bearing
Nut

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6—Instrument Cluster Lighting 8–35
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Student Page

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4—Feedback 8–27
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4—Inspect, Test, Repair and Replace the Components of a Parking Light, Clearance Light and Taillight Circuit 8–75
5—Inspect, Test, Adjust, Repair and Replace the Components of a Stoplight (Brake Light) Circuit 8–79
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7—Inspect, Test, Repair and Replace the Components of a Back-Up Lights Circuit 8–89
8—Inspect, Test, Repair and Replace the Components of an Instrument Lighting Circuit 8–93
9—Inspect, Test, Repair and Replace the Components of a Courtesy Lights Circuit 8–97
10—Inspect, Test, Repair and Replace the Components of Tractor-to-Trailer Lights Circuit 8–101

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Cab Exterior Lighting (Objective 1)
  TM 2—Headlights and Daytime Running Lights Circuit (Objective 1)
  TM 3—Stoplight Switches (Objective 3)
  TM 4—Stoplight and Turn Signal Circuit (Objectives 3 and 4)
  TM 5—Back-Up Lights Switch (Objective 5)
  TM 6—Instrument Cluster Lighting (Objective 6)
  TM 7—Tractor-to-Trailer Connector (Objective 8)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.

Suggested Activities

- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- As each objective is discussed, show students where the parts are located on a vehicle.
- Demonstrate how to access the different types of lights located on a tractor and trailer.
- Show students where back-up light switches are located on various types of transmissions.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Classroom Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Shop Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Chrysler Service Training Programs, *Electrical Diagnosis 1 Student Workbook*, Chrysler, 1994.
- Chrysler Service Training Programs, *Electrical Diagnosis 2 Student Workbook*, Chrysler, 1994.
- Chrysler Service Training Programs, *Electricity and Electronics Section 1, Fundamentals*, Chrysler.
- Chrysler Service Training Programs, *Electricity and Electronics Section 4, Wiring and Accessories*, Chrysler.

Suggested Activities

- Curriculum and Instructional Materials Center, *Engine Repair Specialist*, Oklahoma Department of Vocational and Technical Education, 1993.
- Denton, Tom. *Automobile Electrical and Electronic Systems.* Warrendale, PA: SAE International, 1995.
- Derato, Frank C., *Automotive Electrical and Electronic Systems Shop Manual*, Glencoe/McGraw-Hill.
- Duffy, James E. *Auto Electricity and Electronics Technology.* Tinley Park, IL: Goodheart-Wilcox Co., 1998.
- Fowler, Richard J. *Electricity: Principles and Applications.* New York: Glencoe, 1994.
- GM Service Technology Group, *Electrical Theory and Basic Circuitry*, General Motors Corporation 1991.
- GM Service Technology Group, *Wiring Assembly and Repairs*, General Motors Corporation.
- Halderman, James D. *Automotive Electrical and Electronic Systems: A Worktext.* Englewood Cliffs, NJ: Prentice Hall, 1996.
- Halderman, James D. *Diagnosis and Troubleshooting of Automotive Electrical, Electronic, and Computer Systems.* Upper Saddle River, NJ: Prentice Hall, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual.* Albany, NY: Delmar Publishers, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual.* Albany, NY: Delmar Publishers, 1997.
- Mitchell International. *Domestic Cars Service and Repair 1991.* San Diego, CA: Mitchell International, 1991.
- Santini, Al. *Automotive Electricity and Electronics.* Albany, NY: Delmar Publishers, 1997.
- Santini, Al. *Automotive Electricity and Electronics: Instructor's Guide.* Albany, NY: Delmar Publishers, 1997.
- *Service Training Specialty Training, Automotive Electronics Reference Book*, Ford Parts and Service Division, 1991.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Chapman, Norm. *Principles of Electricity and Electronics for the Automotive Technician*, 1st ed. Albany, NY: Delmar Publishers, 2000.
- Hollembeak, Barry. *Automotive Electricity, Electronics and Computer Controls*, 1st ed. Albany, NY: Delmar Publishers, 1999.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Diagnose the Cause of Headlights and Daytime Running Lights Problems

1. C
2. A
3. A
4. C
5. B
6. C
7. A
8. C
9. A
10. B

Assignment Sheet 2

Diagnose the Cause of Parking Lights, Clearance Lights, and Taillights Problems

1. B
2. C
3. B
4. D
5. B
6. C
7. A
8. B
9. A
10. B

Assignment Sheet 3

Diagnose the Cause of Stoplight (Brake Light) Problems

1. A
2. A
3. C
4. A
5. D
6. D
7. A
8. B

Assignment Sheet 4

Diagnose the Cause of Turn Signals and Hazard Lights Problems

1. B
2. A
3. B
4. A
5. C
6. A
7. C
8. A
9. B
10. A

Assignment Sheet 5

Diagnose the Cause of Back-Up Lights Problems

1. B
2. C
3. C
4. C
5. A
6. B
7. A

Answers to Assignment Sheets

Assignment Sheet 6

Diagnose the Cause of Instrument Lighting Problems

1. A
2. D
3. C
4. C
5. C
6. B
7. C
8. B
9. A
10. C

Assignment Sheet 7

Diagnose the Cause of Courtesy Lights Problems

1. B
2. C
3. A
4. Any three of the following problems in any order are correct:

    - burned fuses
    - faulty circuit breakers
    - burned-out bulbs
    - feedback

5. As determined by instructor
6. A
7. C
8. A
9. B

Written Test

Name ____

Date ________________________________ Score__________

Objective 1

Match the terms related to parts of headlights and daytime running lights circuits to their functions. Write the number of the correct answer in the blank. Definitions continue on the next page.

1. Battery
2. Circuit breaker
3. Connector
4. Dimmer switch
5. Fusible link
6. Ground circuit
7. Headlight
8. Headlight relays
9. Headlight retaining screws
10. Headlight switch
11. High-beam indicator
12. Horizontal adjusting screw
13. Vertical adjusting screw
14. Wiring
15. Wiring harnesses

_____ a. Identifies if the high-beam circuit is complete

_____ b. A common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

_____ c. Directs current flow to the high or low beam filaments of headlight bulbs

_____ d. Uses a low current, provided by a switch, to control a higher current going to the headlights

_____ e. A grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

_____ f. Controls current flow to the circuit

_____ g. Illuminates when current is flowing to the filament of the bulb in the self-contained unit

_____ h. Provides electrical current directly to the headlight switch

_____ i. Protects components of the circuit from excessive current flow

_____ j. Connects components of the lighting circuit to the battery and/or each other

____ k. Protects components of the circuit from temporary current overloads

____ l. Fastens headlights into place

____ m. Used to adjust the headlight beam from side to side

____ n. Plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

____ o. Used to adjust the headlight beam up and down

Objective 2

Match the terms related to parts of parking lights, taillights, clearance lights, and marker lights circuits to their functions. Write the number of the correct answer in the blank.

1. Clearance/marker lights
2. Circuit breaker
3. Connector
4. Fusible link
5. Ground circuit
6. Headlight switch
7. License plate light/bulb circuit
8. Parking lights
9. Relay
10. Taillights

____ a. Illuminates the license plate

____ b. Protects components from excessive current flow

____ c. Protects components of the circuit from short circuits and current overloads

____ d. An electrical switch that allows a small current to control a much larger one

____ e. A common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

____ f. Plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

____ g. Provides illumination for parking the vehicle

____ h. Controls current flow to the circuit

____ i. Lights designed to outline the tractor, straight truck body, or trailer dimensions

____ j. Provides illumination for the stop, tail, directional, backup, and license plate systems

Objective 3

Match the terms related to parts of a stoplight circuit to their functions. Write the number of the correct answer in the blank.

1. Brake pedal
2. Brake light bulbs
3. Brake switch (electric)
4. Brake switch (air)
5. Fuse
6. Ground circuit
7. Turn signal switch

_____ a. Protects components of the circuit from short circuits and current overloads

_____ b. A tactile sensor reacting to the amount of pressure applied to activate the brake switch

_____ c. Guides current to flow to the turn signal light bulbs

_____ d. Allows current to flow to the stop light bulbs

_____ e. An electro-pneumatic switch that operates in conjunction with the brake valve to complete the circuit to the brake light bulbs

_____ f. Illuminates taillight unit

_____ g. A common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

Objective 4

Match the terms related to parts of a turn signal and hazard lights circuit to their functions. Write the number of the correct answer in the blank.

1. Flasher unit
2. Turn signal light bulbs
3. Indicator bulbs
4. Turn signal switch

_____ a. Illuminates the turn signal and hazard circuit

_____ b. Alerts the driver to the direction of the electrical current flowing to the signal lights

_____ c. Guides current to the right or left front and rear of the vehicle taillights

_____ d. Opens and closes the turn signal circuit providing intermittent current to the side turn signal light bulbs, taillights, and instrument panel lights

Written Test

Objective 5

Match the terms related to parts of a back-up lights circuit to their functions. Write the number of the correct answer in the blank

1. Back-up lights bulbs
2. Back-up light switch
3. Gear shift or transmission switch

_____ a. Allows current to flow to the back-up light switch when the transmission is shifted into reverse

_____ b. Illuminates the taillight unit

_____ c. Allows current to flow to the back-up light bulbs when the transmission-mounted switch is shifted into reverse

Objective 6

Match the terms related to parts of an instrument lighting circuit to their functions. Write the number of the correct answer in the blank

1. Connector
2. Fiber optic conductors
3. Fiber optic strands
4. Ground circuit
5. Headlight switch
6. Panel illumination light bulbs
7. Printed circuit board
8. Relay
9. Rheostat

_____ a. Controls current flow to the circuit

_____ b. Instrument light bulbs, fiber optics, and circuits printed on a panel board

_____ c. Plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

_____ d. Increases or decreases current flow to instrument panel bulbs to control brightness

_____ e. Reflects the light from the panel illumination bulbs to lens on the instrument panel

_____ f. Controls current by switching current on and off rapidly to the panel light circuit

_____ g. Insulates the fiber optic strands

_____ h. A common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

_____ i. Provides indirect lighting to illuminate the instrument panel

Written Test

Objective 7

Match the terms related to parts of a courtesy lights circuit to their functions. Write the number of the correct answer in the blank.

1. Cigar lighter	5. Ground switch
2. Connector	6. Headlight switch
3. Door-jam switches	7. Left and right courtesy lights
4. Baggage compartment bulb	8. Reading/map light

_____ a. Illuminates the baggage compartment

_____ b. Plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

_____ c. Illuminates a specific interior area with an intense light

_____ d. Connects current flow to the circuit

_____ e. Connects current to ground

_____ f. Provides electric current to accessories or to the metal coil

_____ g. Light bulbs that illuminate the left and right side of the interior of a vehicle when the door is open or when the headlight switch is rotated to a counter clockwise position

_____ h. Connects current to ground wire

Objective 8

Complete statements concerning the parts of a tractor-to-trailer multi-wire connector by circling the correct answers.

a. Seven-conductor electrical plug—connector with seven (**male, female**) contacts.

b. Seven-conductor electrical receptacle—connector with seven (**male, female**) contacts.

c. Junction block—located at the (**instrument, circuit breaker**) panel, this is where the trailer wiring harness usually connects to the electrical system.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 11
b. 6
c. 4
d. 8
e. 15
f. 10
g. 7
h. 1
i. 5
j. 14
k. 2
l. 9
m. 12
n. 3
o. 13

Objective 2

a. 7
b. 4
c. 2
d. 9
e. 5
f. 3
g. 8
h. 6
i. 1
j. 10

Objective 3

a. 5
b. 1
c. 7
d. 3
e. 4
f. 2
g. 6

Objective 4

a. 2
b. 3
c. 4
d. 1

Objective 5

a. 3
b. 1
c. 2

Objective 6

a. 5
b. 7
c. 1
d. 9
e. 3
f. 8
g. 2
h. 4
i. 6

Objective 7

a. 4
b. 2
c. 8
d. 6
e. 3
f. 1
g. 7
h. 5

Objective 8

a. female
b. male
c. instrument

Unit 8 Lighting Systems Diagnosis & Repair

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objective 1.

☐ 4. **Read** Student Supplement 1, "Lighting Systems", Student Supplement 2, "Headlight Diagnosis Chart", and Student Supplement 3, "The Headlight Switch".

☐ 5. **Do** Assignment Sheet 1, "Diagnose the Cause of Headlights and Daytime Running Lights Problems".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat Steps 3, 4, and 5.

☐ 7. **Do** Job Sheet 1, "Inspect, Replace, and Aim Headlights/Bulbs".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 7.

☐ 9. **Do** Job Sheet 2, "Inspect, Test, and Replace Light Bulbs and Test Sockets".

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 9.

☐ 11. **Do** Job Sheet 3, "Inspect, Test, Repair and Replace the Components of a Headlights and Daytime Running Lights Circuit".

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 11.

☐ 13. **Study** Information Sheet, Objective 2.

☐ 14. **Read** Student Supplement 4, "Feedback".

☐ 15. **Do** Assignment Sheet 2, "Diagnose the Cause of Parking Lights, Clearance Lights, and Taillights Problems".

☐ 16. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, repeat Steps 13, 14, and 15.

☐ 17. **Do** Job Sheet 4, "Inspect, Test, Repair and Replace the Components of a Parking Light, Clearance Light and Taillight Circuit".

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 17.

☐ 19. **Study** Information Sheet, Objective 3.

☐ 20. **Do** Assignment Sheet 3, "Diagnose the Cause of Stoplight (Brake Light) Problems".

☐ 21. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 22. If the evaluation is not satisfactory, repeat Steps 19 and 20.

☐ 22. **Do** Job Sheet 5, "Inspect, Test, Adjust, Repair, and Replace the Components of a Stoplight (Brake Light) Circuit".

☐ 23.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 22.
☐ 24.	**Study**	Information Sheet, Objective 4.
☐ 25.	**Read**	Student Supplement 5, "Turn Signal and Hazard Light Malfunction Chart".
☐ 26.	**Do**	Assignment Sheet 4, "Diagnose the Cause of Turn Signals and Hazard Lights Problems".
☐ 27.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 28. If the evaluation is not satisfactory, repeat Steps 24, 25, and 26.
☐ 28.	**Do**	Job Sheet 6, "Inspect, Test, Repair and Replace the Components of a Turn Signal and Hazard Light Circuit".
☐ 29.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 30. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 28.
☐ 30.	**Study**	Information Sheet, Objective 5.
☐ 31.	**Do**	Assignment Sheet 5, "Diagnose the Cause of Back-Up Lights Problems".
☐ 32.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 33. If the evaluation is not satisfactory, repeat Steps 30 and 31.
☐ 33.	**Do**	Job Sheet 7, "Inspect, Test, Repair, and Replace the Components of a Back-Up Lights Circuit".
☐ 34.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 35. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 33.

Learning Activities Sheet

☐ 35. **Study** Information Sheet, Objective 6.

☐ 36. **Do** Assignment Sheet 6, "Diagnose the Cause of Instrument Lighting Problems".

☐ 37. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 38. If the evaluation is not satisfactory, repeat Steps 35 and 36.

☐ 38. **Do** Job Sheet 8, "Inspect, Test, Repair and Replace the Components of an Instrument Lighting Circuit".

☐ 39. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 40. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 8 and repeat Step 38.

☐ 40. **Study** Information Sheet, Objective 7.

☐ 41. **Do** Assignment Sheet 7, "Diagnose the Cause of Courtesy Lights Problems".

☐ 42. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 43. If the evaluation is not satisfactory, repeat Steps 40 and 41.

☐ 43. **Do** Job Sheet 9, "Inspect, Test, Repair, and Replace the Components of a Courtesy Lights Circuit".

☐ 44. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 45. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 9 and repeat Step 43.

☐ 45. **Study** Information Sheet, Objective 8.

☐ 46. **Read** Student Supplement 6, "Trailer Lighting".

☐ 47. **Do** Job Sheet 10, "Inspect, Test, Repair, and Replace the Components of Tractor-to-Trailer Lights Circuit".

☐ 48. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 49. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 10 and repeat Steps 46 and 47.

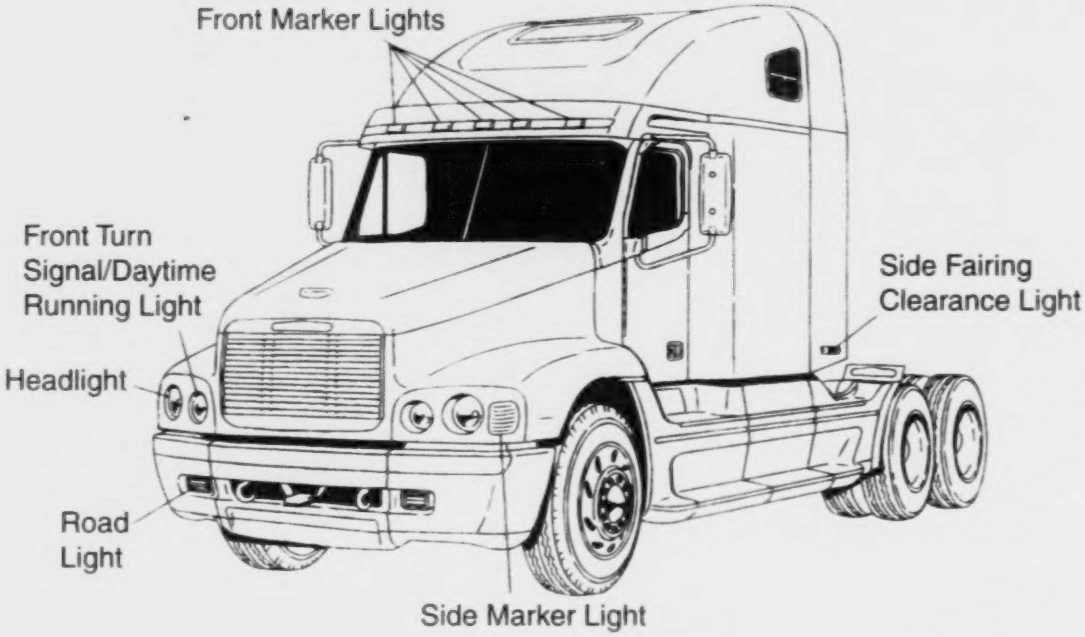
☐ 49. **Check** With instructor for any additional assignments to be completed.

☐ 50. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 51. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

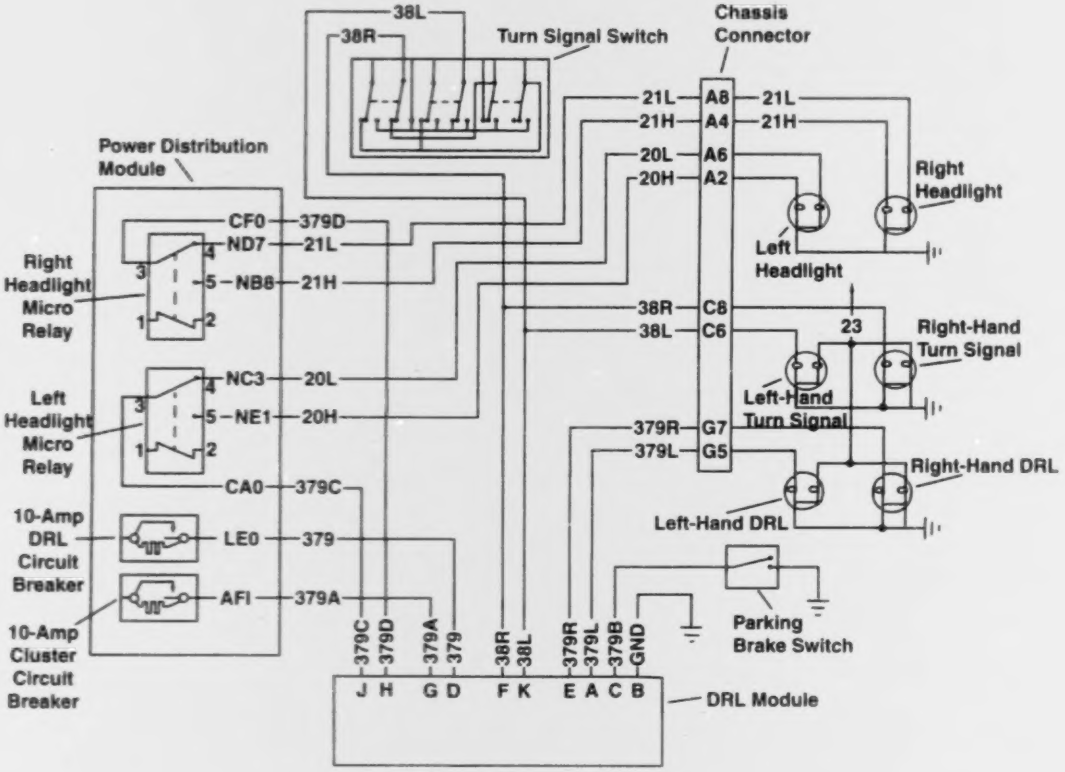
***Permission to duplicate this form is granted.**

Cab Exterior Lighting


Front Marker Lights
Front Turn Signal/Daytime Running Light
Headlight
Road Light
Side Marker Light
Side Fairing Clearance Light

Courtesy of Freightliner LLC

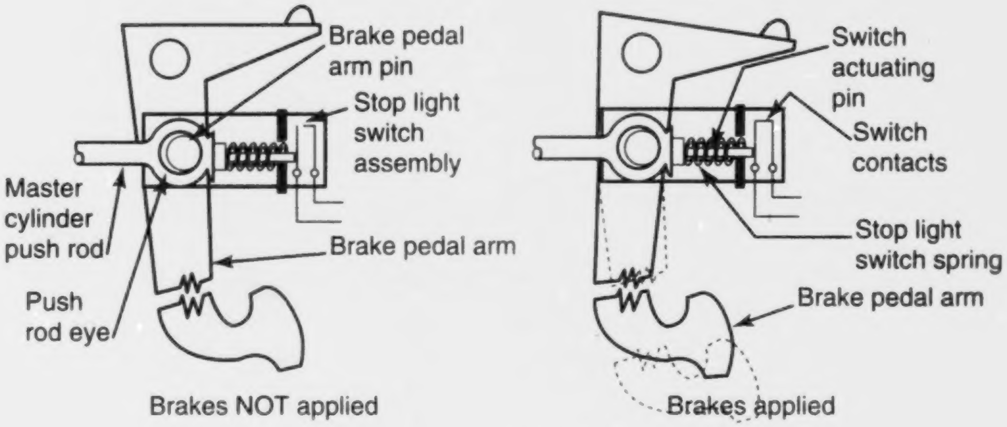
Headlights and Daytime Running Lights Circuit


38L
38R
Turn Signal Switch
Chassis Connector
Power Distribution Module
21L
21H
20L
20H
A8
A4
A6
A2
Right Headlight
Left Headlight
CF0
379D
ND7
NB8
Right Headlight Micro Relay
3
4
5
1
2
23
38R
38L
C8
C6
Right-Hand Turn Signal
Left-Hand Turn Signal
Left Headlight Micro Relay
NC3
NE1
379R
379L
G7
G5
Right-Hand DRL
Left-Hand DRL
CA0
379C
10-Amp DRL Circuit Breaker
LE0
379
10-Amp Cluster Circuit Breaker
AFI
379A
Parking Brake Switch
379B
GND
J
H
G
D
F
K
E
A
C
B
DRL Module

Courtesy of Freightliner LLC

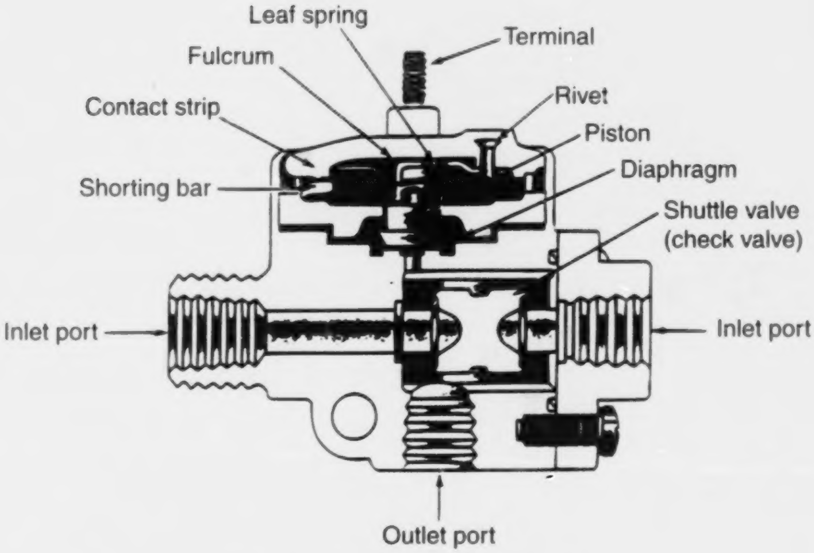
400

Stoplight Switches


Brake pedal arm pin
Stop light switch assembly
Master cylinder push rod
Brake pedal arm
Push rod eye
Brakes NOT applied
Switch actuating pin
Switch contacts
Stop light switch spring
Brake pedal arm
Brakes applied

Used with permission of Ford Motor Co.

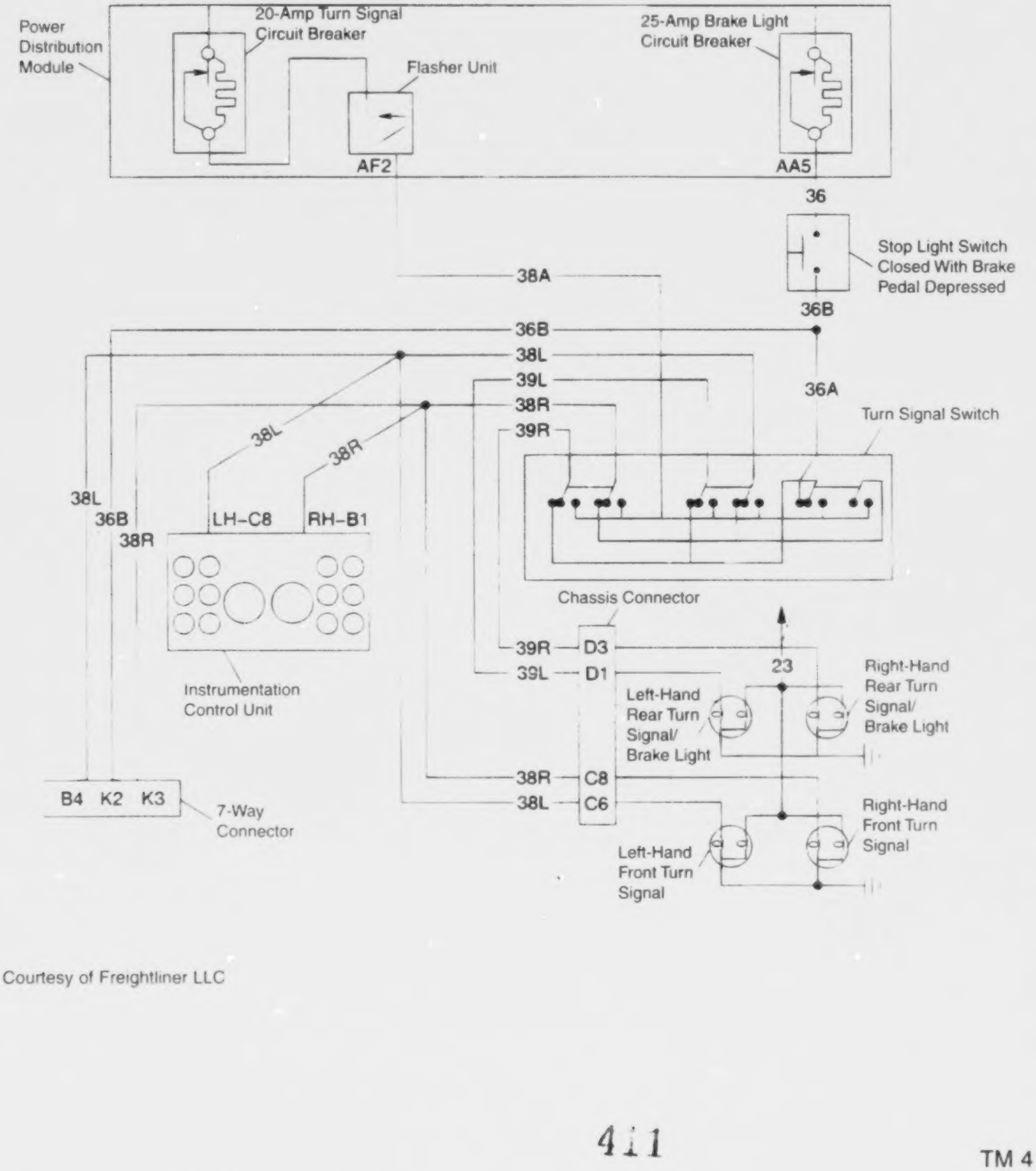
Typical Stop Light Switch


Leaf spring
Terminal
Fulcrum
Rivet
Contact strip
Piston
Shorting bar
Diaphragm
Shuttle valve (check valve)
Inlet port
Inlet port
Outlet port

Stop Light Switch on Air Brake Equipped Truck

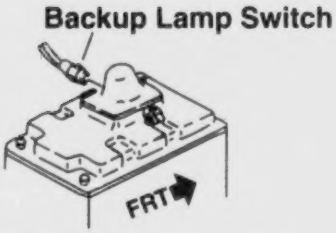
TM 3

Stoplight and Turn Signal Circuit

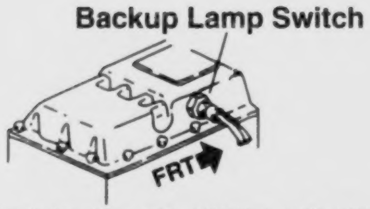

Power Distribution Module
20-Amp Turn Signal Circuit Breaker
Flasher Unit
25-Amp Brake Light Circuit Breaker
AF2
AA5
36
Stop Light Switch Closed With Brake Pedal Depressed
36B
38A
36B
38L
39L
38R
39R
36A
Turn Signal Switch
38L
38R
38L
36B
38R
LH–C8
RH–B1
Instrumentation Control Unit
Chassis Connector
39R — D3
39L — D1
23
Left-Hand Rear Turn Signal/ Brake Light
Right-Hand Rear Turn Signal/ Brake Light
38R — C8
38L — C6
B4 K2 K3
7-Way Connector
Left-Hand Front Turn Signal
Right-Hand Front Turn Signal

Courtesy of Freightliner LLC

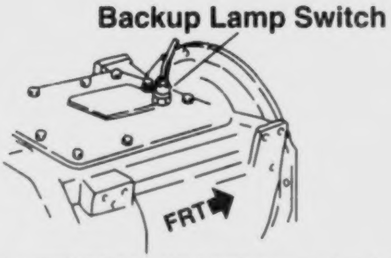
Back-Up Light Switches


Backup Lamp Switch
FRT

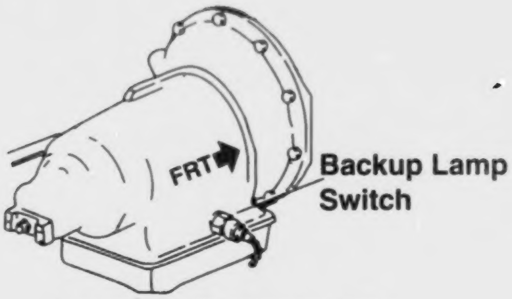
SM/CH 465 Transmission


Backup Lamp Switch
FRT

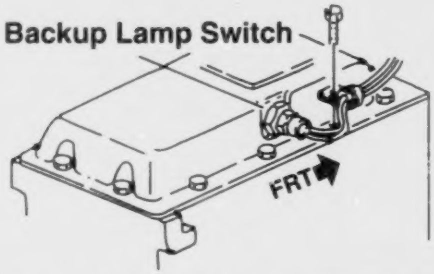
Clark/Fuller FS 4005B, FS 4005C
FS 5005A, FS 5005C Transmissions


Backup Lamp Switch
FRT

Fuller RT 6610, 6613 Transmissions
(Similar Location for Fuller FS 6106)


FRT
Backup Lamp Switch

Automatic Transmissions


Backup Lamp Switch
FRT

Spicer CM 6052 Transmissions

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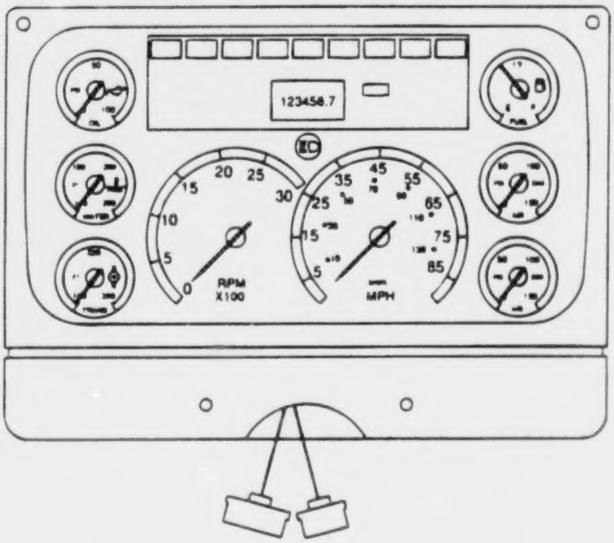
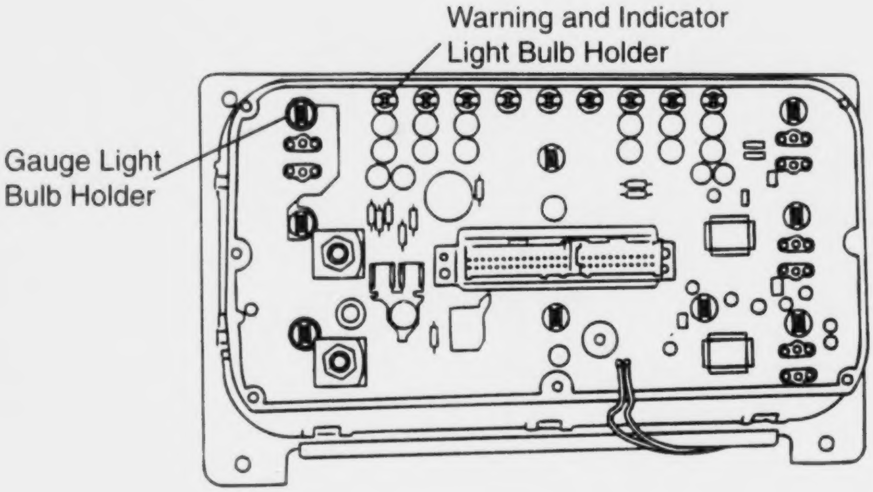
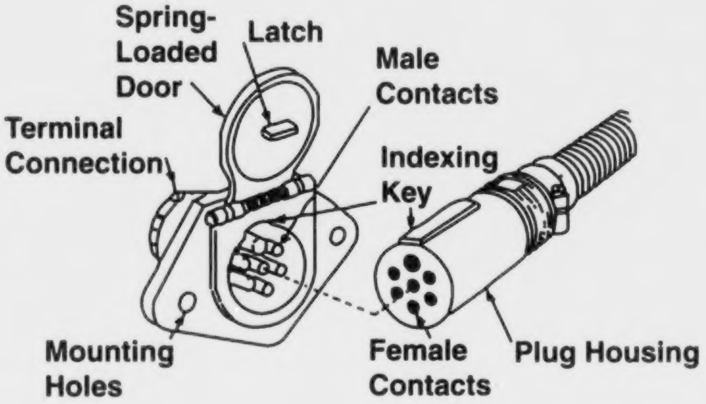
Instrument Cluster Lighting


123456.7
15
20
25
30
10
5
0
RPM
X100
35
45
55
25
65
15
75
5
85
MPH


Warning and Indicator
Light Bulb Holder
Gauge Light
Bulb Holder

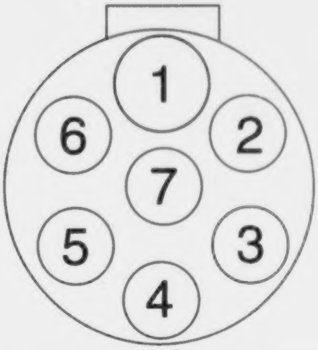
Courtesy of Freightliner LLC

Tractor-to-Trailer Connector


Spring-Loaded Door
Latch
Male Contacts
Terminal Connection
Indexing Key
Mounting Holes
Female Contacts
Plug Housing

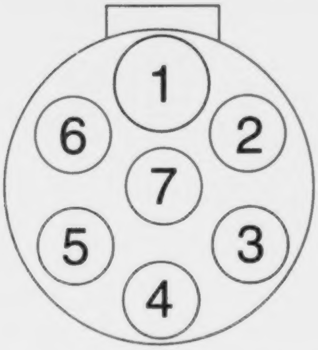
RECEPTACLE PLUG

J560 Connector on Trailer



Number	Color	Function
1	White	Ground (shared)
2	Black	Marker Lights
3	Yellow	Left Turn Indicator Lights
4	Red	Stop Lights
5	Green	Right Turn Indicator Lights
6	Brown	Tail Lights
7	Blue	ABS Power (new) or Auxiliary, Switched (old)

J560 Yellow Connector on Trailer



Number	Color	Function
1	White	Ground (shared)
2	Black	Optional
3	Yellow	ABS Malfunction Light
4	Red	Optional
5	Green	Optional
6	Brown	Optional
7	Blue	ABS Power

Unit 9 Driver Information Systems Diagnosis & Repair

Unit Contents

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Student Page

Student Components

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2—Diagnose the Cause(s) of the Faulty Operation of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit 9–25
3—Diagnose the Cause(s) of the Faulty Operation of Audible Warning Devices 9–31

Unit Contents

Job Sheets

1—Inspect, Test, Repair, and Replace the Components of a Gauge Circuit 9–35
2—Inspect, Test, Repair, and Replace the Components of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit 9–39
3—Inspect, Test, Repair, and Replace Components of Audible Warning Device Circuits 9–43
4—Inspect, Test, Replace, and Calibrate Electronic Speedometer, Odometer, and Tachometer Circuits 9–47

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Bimetallic Gauge (Objective 2)
TM 2—Electromagnetic Gauge (Objective 2)
TM 3—Fuel Gauge Sending Unit Using a Mechanical Variable Resistor (Potentiometer) (Objective 3)
TM 4—Oil Pressure Sending Unit with Piesoresistive Sensor(Objective 3)
TM 5—Engine Temperature Sending Unit with Thermistor (Objective 3)
TM 6—Bimetallic Gauge Circuit (Objective 4)
TM 7—Electromagnetic Two-Coil Gauge Circuit (Objective 4)
TM 8—Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit (Objective 6)
TM 9—Audible Warning Device Circuit (Objective 9)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Suggested Activities

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Have students use trade magazines or internet-accessible sites to locate and read two articles on electronic gauges. Have them report verbally or write a summary paragraph about each article.
- Disassemble bimetallic, electromagnetic, and electronic gauges to demonstrate the differences between their construction.
- Gather a potentiometer, piesoresistor, thermistor, and pulse generator and explain to students how each one works and when and where each should be used.
- Provide a circuit diagram of an electronic instrument cluster to students and have them trace each individual circuit.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Classroom Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Shop Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.

Suggested Activities

- Chrysler Service Training Programs, *Electrical Diagnosis 1 Student Workbook*, Chrysler, 1994.
- Chrysler Service Training Programs, *Electrical Diagnosis 2 Student Workbook*, Chrysler, 1994.
- Chrysler Service Training Programs, *Electricity and Electronics Section 1, Fundamentals*, Chrysler.
- Chrysler Service Training Programs, *Electricity and Electronics Section 4, Wiring and Accessories*, Chrysler.
- Curriculum and Instructional Materials Center, *Engine Repair Specialist*, Oklahoma Department of Vocational and Technical Education, 1993.
- Denton, Tom. *Automobile Electrical and Electronic Systems*. Warrendale, PA: SAE International, 1995.
- Derato, Frank C., *Automotive Electrical and Electronic Systems Shop Manual*, Glencoe/McGraw-Hill.
- Duffy, James E. *Auto Electricity and Electronics Technology*. Tinley Park, IL: Goodheart-Wilcox Co., 1998.
- Ford Motor Company, *Basic Automotive Electronics, Part Four*, Ford Motor Company.
- Fowler, Richard J. *Electricity: Principles and Applications*. New York: Glencoe, 1994.
- GM Service Technology Group, *Electrical Theory and Basic Circuitry*, General Motors Corporation 1991.
- GM Service Technology Group, *Wiring Assembly and Repairs*, General Motors Corporation.
- Halderman, James D. Automotive *Electrical and Electronic Systems: A Worktext*. Englewood Cliffs, NJ: Prentice Hall, 1996.
- Halderman, James D. *Diagnosis and Troubleshooting of Automotive Electrical, Electronic, and Computer Systems*. Upper Saddle River, NJ: Prentice Hall, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual*. Albany, NY: Delmar Publishers, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual*. Albany, NY: Delmar Publishers, 1997.

- Mitchell International. *Domestic Cars Service and Repair 1991*. San Diego, CA: Mitchell International, 1991.
- Santini, Al. *Automotive Electricity and Electronics*. Albany, NY: Delmar Publishers, 1997.
- Santini, Al. *Automotive Electricity and Electronics: Instructor's Guide*. Albany, NY: Delmar Publishers, 1997.
- *Service Training Specialty Training, Automotive Electronics Reference Book*, Ford Parts and Service Division, 1991.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*, 1st ed. Albany, NY: Delmar Publishers, 1999.
- Chapman, Norm. *Principles of Electricity and Electronics for the Automotive Technician*, 1st ed. Albany, NY: Delmar Publishers, 2000.
- Hollembeak, Barry. *Automotive Electricity, Electronics and Computer Controls*, 1st ed. Albany, N[illegible] Delmar Publishers, 1999.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Diagnose the Cause(s) of Faulty Gauge Readings

1. A
2. B
3. B
4. A
5. C
6. C
7. A
8. B
9. B
10. Answer may vary

Assignment Sheet 2

Diagnose the Cause(s) of the Faulty Operation of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit

1. D
2. A
3. D
4. A
5. B
6. A
7. B

Assignment Sheet 3

Diagnose the Cause(s) of the Faulty Operation of Audible Warning Devices

1. B
2. A
3. C
4. A
5. D

Written Test

Name ____

Date ______________________________ Score__________

Objective 1

Match the basic categories of gauges to the descriptions of their operations. Write the number of the correct answer in the blank:

1. Bimetallic gauge
2. Electronic (digital) gauge
3. Electromagnetic gauge

_____ a. Converts the heating effect of electricity into mechanical movement

____ b. Converts the interaction of electromagnets into mechanical movement

____ c. Converts an analog signal into a digital display

Objective 2

Match the types of gauges to descriptions of their operations. Write the number of the correct answer in the blank.

1. Bimetallic gauge
2. Electromagnetic gauge
3. Electronic (digital) gauge

_____ a. A permanent magnet surrounded by one or more types of magnets that use the interaction of like and unlike poles to move a pointer or needle along the calibrated scale of the gauge

____ b. A U-shaped strip that bends in proportion to the heat from an attached heating coil to move a pivoted needle or pointer along the calibrated scale of the gauge

____ c. Receives information from a sensor that contains a permanent magnet creating a magnetic field that when broken, generates an AC voltage sent to a computer module that performs computations and displays the information to the gauge

Written Test

Objective 3

Match types of gauge sending units to descriptions of their operations. Write the number of the correct answer in the blank.

1. Mechanical variable resistor (potentiometer)
2. Piesoresistor
3. Thermistor
4. Pulse generator

______ a. Resistance value changes in proportion to pressure changes; measures oil pressure

____ b. Resistance value changes in proportion to position of device; measures fuel levels

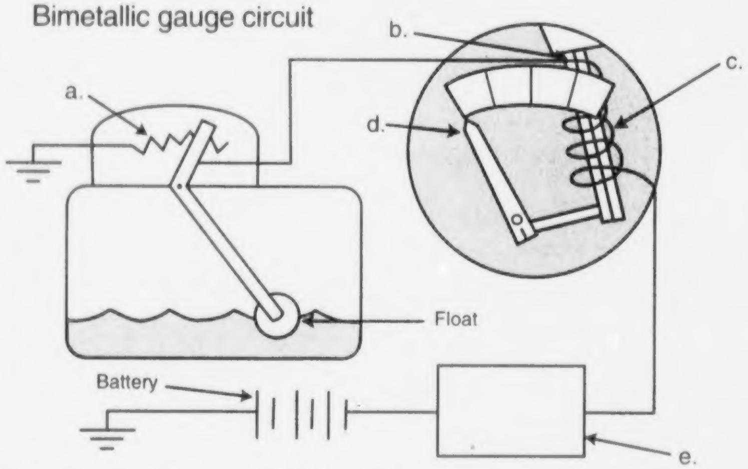
____ c. Converts mechanical motion to an alternating current pulse that a microprocessor or gauge converts to revolutions per minute or miles per hours

____ d. Resistance value changes in proportion to temperature changes; measures engine coolant temperature

Objective 4

Label the parts of a gauge circuit. Write the correct name of the part in the space provided.

Bimetallic gauge circuit



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a. ______________________________

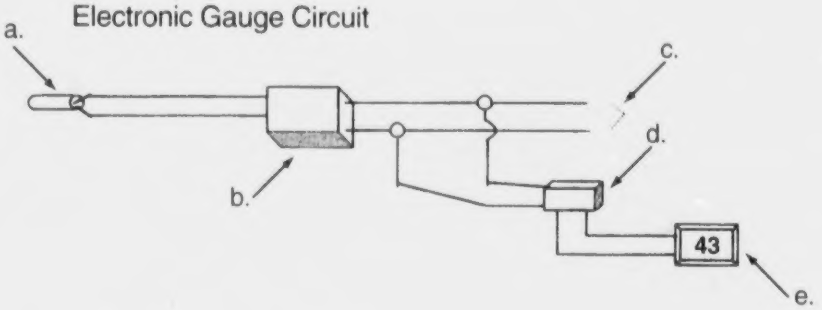
b ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

Electronic Gauge Circuit



a. ____

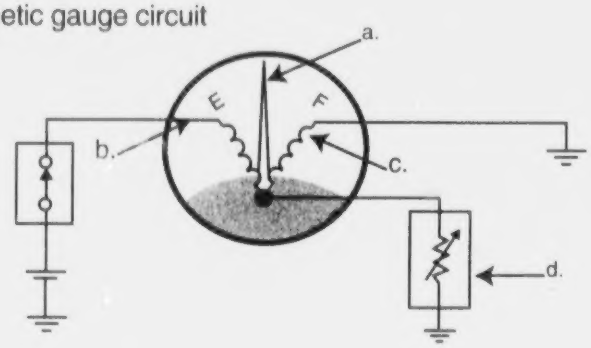
b. ____

c. ____

d. ____

e. ____

Electromagnetic gauge circuit



a. ____

b. ____

c. ____

d. ____

Written Test

Objective 5

Match the names of the parts of a gauge circuit to descriptions of their functions. Write the number of the correct answer in the blank.

1. Bimetallic arm
2. Data buss
3. Digital display
4. ECM
5. Electromagnetic coils
6. Heating coil
7. Instrument voltage regulator
8. Interface module
9. Pulse generator
10. Sending unit
11. Needle or pointer

_____ a. Current proportionally flows through it to the bimetallic arm in direct response to resistance values of the sending unit

_____ b. Can be of several different types, such as a computerized dash, or a stand-alone gauge that interrupts the signal and displays the information

_____ c. Receives the information it requests from the ECM; then sends this digital information to several different types of displays

_____ d. Changes resistance values to the circuit in response to changes in the system being monitored

_____ e. Converts analog pulses to digital data and sends them over the data buss

_____ f. Moves in response to either the magnetic fields of coils E and F, or movement of the bimetallic arm

_____ g. Provides a steady, consistent electrical current to the gauge

_____ h. Bends or flexes to move a needle or pointer in proportion to the amount of heat from the heating coil

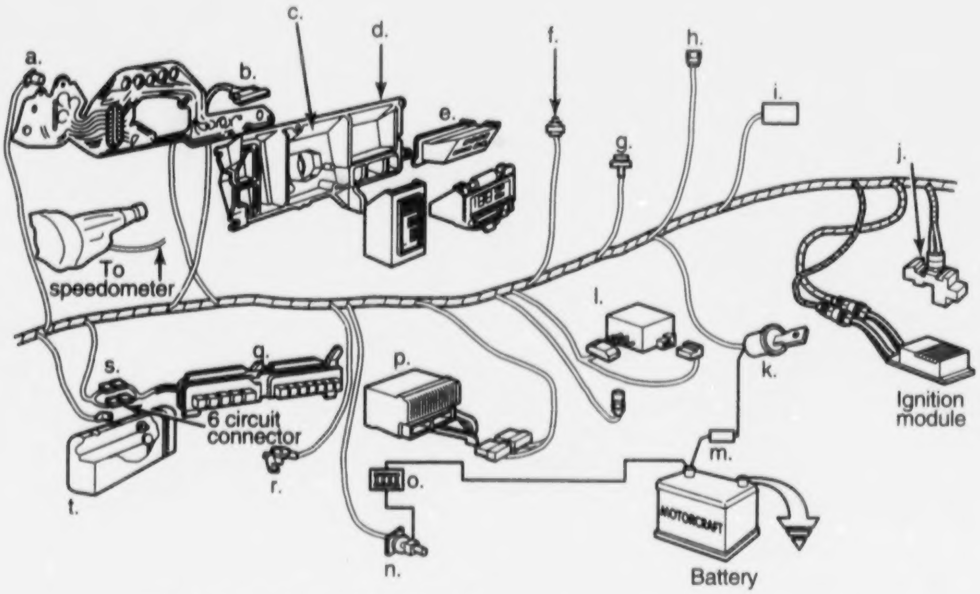
_____ i. Sends a number of analog AC pulses, per revolution, to the microprocessor

_____ j. Uses current flow to produce a strong magnetic field to attract the needle or pointer

_____ k. A digital 2-way communication highway for several processors that request information from the ECM

Objective 6

Label the parts of an electronic instrument cluster, warning light, indicator light, and driver information circuit. Write the correct name of the part in the space provided.


a.
b.
c.
d.
e.
f.
g.
h.
i.
j.
To speedometer
l.
s.
q.
p.
k.
Ignition module
6 circuit connector
m.
o.
t.
r.
n.
MOTORCRAFT
Battery

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a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

k. ______________________________

l. ______________________________

m. ______________________________

Written Test

n. ____

o. ____

p. ____

q. ____

r. ____

s. ____

t. ____

Objective 7

Match the names of the parts of an electronic instrument cluster, warning light, indicator light, and driver information circuit to descriptions of their functions. Write the number of the correct answer in the blank. Definitions continue on the next page.

1. Circuit connector
2. Alternator and alternator warning voltage regulator
3. Door ajar switches
4. Dual brake warning switch
5. Electronic instrument display module
6. Engine oil pressure sending unit
7. Engine temperature sending unit
8. Fuel tank sending unit
9. Power distribution module
10. Ground
11. Headlight switch and dimming rheostat
12. Ignition switch
13. Keyboard assembly
14. Light bulb outage module
15. Message center display
16. Message center logic module
17. Relay
18. Seat belt warning light
19. Tone generator
20. Windshield washer fluid sensing unit

_____ a. Increases or decreases resistance in the circuit to produce increased or decreased instrument panel lighting

____ b. Displays various operating information for the driver

____ c. Processes electrical input and applies an appropriate message signal for display

____ d. Uses a thermistor sensor that changes resistance as temperature changes the input information to the message center logic module

____ e. Device by which operator data-entry can determine various trip log/fuel economy function

____ f. Connects and disconnects the circuit from the voltage as the switch is moved to the open or closed position

____ g. Connects and disconnects the circuit from the voltage when the brake is applied

____ h. As the level changes, the float moves the sliding contact on a potentiometer which changes the resistance in the circuit

____ i. Provides a steady, consistent electrical current to the alternator and alternator warning system

____ j. Reflects seat belt not in use

____ k. As the windshield washer fluid level changes, the windshield washer level float moves the sliding contact on a potentiometer

____ l. Holds paired terminals firmly in place, making sure the terminals stay in contact despite the normal vibration of the vehicle

____ m. Processes electrical input and applies an appropriate light display to reflect light bulb's outage

____ n. Processes electrical input and applies an appropriate audible signal

____ o. Uses a piesoresistive sensor that changes resistance in proportion to pressure changes

____ p. Holds fuses and circuit breakers

____ q. Reflects a variety of information from monitored engine systems

____ r. Connects and disconnects the circuit from the voltage when the door is opened and closed

____ s. Processes electrical input and applies an appropriate message signal for display

____ t. Conducts current from the vehicle body to the negative terminal of the battery

Objective 8

List the types of driver information commonly given by an audible warning device. Write the answer in the blank lines.

____

____

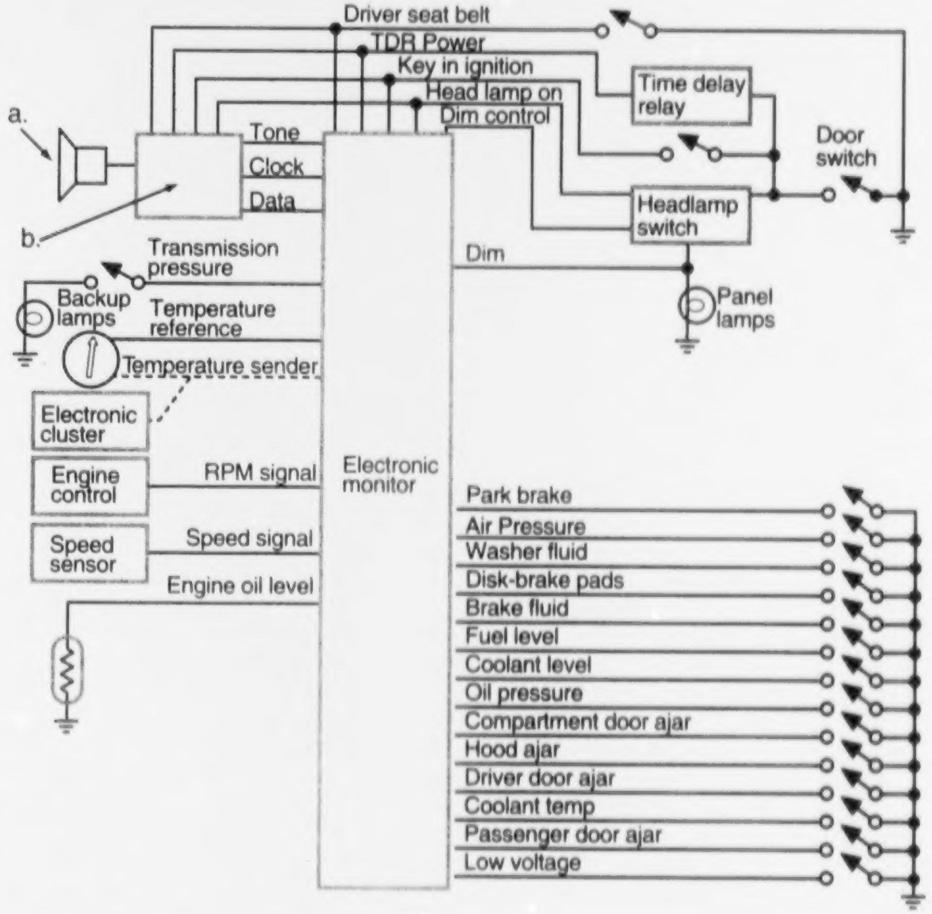
____

____

____

Objective 9

Label the parts of an audible warning device circuit. Write the correct name of the part in the space provided.


a.
b.
Driver seat belt
TDR Power
Key in ignition
Head lamp on
Dim control
Time delay relay
Door switch
Tone
Clock
Data
Headlamp switch
Transmission pressure
Dim
Backup lamps
Temperature reference
Panel lamps
Temperature sender
Electronic cluster
Engine control
RPM signal
Electronic monitor
Speed sensor
Speed signal
Engine oil level
Park brake
Air Pressure
Washer fluid
Disk-brake pads
Brake fluid
Fuel level
Coolant level
Oil pressure
Compartment door ajar
Hood ajar
Driver door ajar
Coolant temp
Passenger door ajar
Low voltage

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a. ______________________________

b. ______________________________

Objective 10

Distinguish between outputs of an audible warning device circuit by placing an "S" next to the description of the function of a speaker, and a "T" next to the description of the function of a tone generator. Write your answer in the blank.

____ a. Processes electrical input and applies an appropriate audible signal

____ b. Amplifies sound

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 1
b. 3
c. 2

Objective 2

a. 2
b. 1
c. 3

Objective 3

a. 2
b. 1
c. 4
d. 3

Objective 4

Bimetallic gauge circuit

a. Fuel sending unit
b. Permanent magnet
c. Heating coil
d. Pointer charge
e. Ignition switch

Electronic gauge circuit

a. Pulse generator
b. ECM
c. Data buss
d. Interface module
e. Digital display

Electromagnetic gauge circuit

a. Pointer magnet
b. Coil
c. Coil
d. Fuel sending unit

Objective 5

a. 6
b. 3
c. 8
d. 10
e. 4
f. 11
g. 7
h. 1
i. 9
j. 5
k. 2

Answers to Written Test

Objective 6

a. Ground
b. Circuit connector
c. Seat belt warning light
d. Electronic instrument display module
e. Message center display
f. Engine oil pressure sending unit
g. Windshield washer fluid sending unit
h. Engine temperature
i. Alternator and alternator warning voltage regulator
j. Dual brake warning switch
k. Ignition switch
l. Tone generator
m. Relay
n. Headlight switch and dimming rheostat
o. Fuse panel
p. Message center logic module
q. Keyboard assembly
r. Door ajar switches
s. Circuit connector
t. Fuel tank sending unit

Objective 7

a. 11
b. 5
c. 17
d. 7
e. 13
f. 12
g. 4
h. 8
i. 2
j. 18
k. 20
l. 1
m. 14
n. 19
o. 6
p. 9
q. 15
r. 3
s. 16
t. 10

Objective 8

Answer should include all of the following in any order.

- Anti-theft system activated
- Door ajar
- Headlight on
- Key in ignition
- Low fuel
- Low oil pressure
- Seat belts not buckled
- Low air pressure
- High temperature
- Low coolant
- Low voltage

Objective 9

a. Speaker
b. Tone generator

Objective 10

a. T
b. S

Unit 9 Driver Information Systems Diagnosis & Repair

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 5.

☐ 4. **Read** Student Supplement 1, "Gauges and Sending Units".

☐ 5. **Do** Assignment Sheet 1, "Diagnose the Cause(s) of Faulty Gauge Readings".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat steps 3, 4, and 5.

☐ 7. **Do** Job Sheet 1, "Inspect, Test, Repair, and Replace the Components of a Gauge Circuit".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat step 7.

☐ 9. **Study** Information Sheet, Objectives 6 and 7.

☐ 10. **Do** Assignment Sheet 2, "Diagnose the Cause(s) of the Faulty Operation of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit".

Learning Activities Sheet

☐ 11. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, repeat steps 9 and 10.

☐ 12. **Do** Job Sheet 2, "Inspect, Test, Repair, and Replace the Components of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit".

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat step 12.

☐ 14. **Study** Information Sheet, Objectives 8, 9, and 10.

☐ 15. **Do** Assignment Sheet 3, "Diagnose the Cause(s) of the Faulty Operation of Audible Warning Devices".

☐ 16. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, repeat steps 14 and 15.

☐ 17. **Do** Job Sheet 3, "Inspect, Test, Repair, and Replace Components of Audible Warning Device Circuits".

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat step 17.

☐ 19. **Do** Job Sheet 4, "Inspect, Test, Replace, and Calibrate Electronic Speedometer, Odometer, and Tachometer Circuits".

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat step 21.

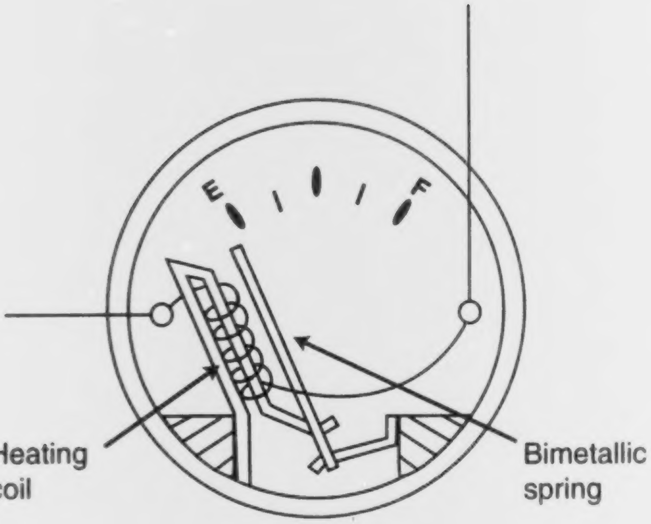
☐ 21. **Check** With instructor for any additional assignments to be completed.

☐ 22. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 23. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Bimetallic Gauge


E
F
Heating coil
Bimetallic spring

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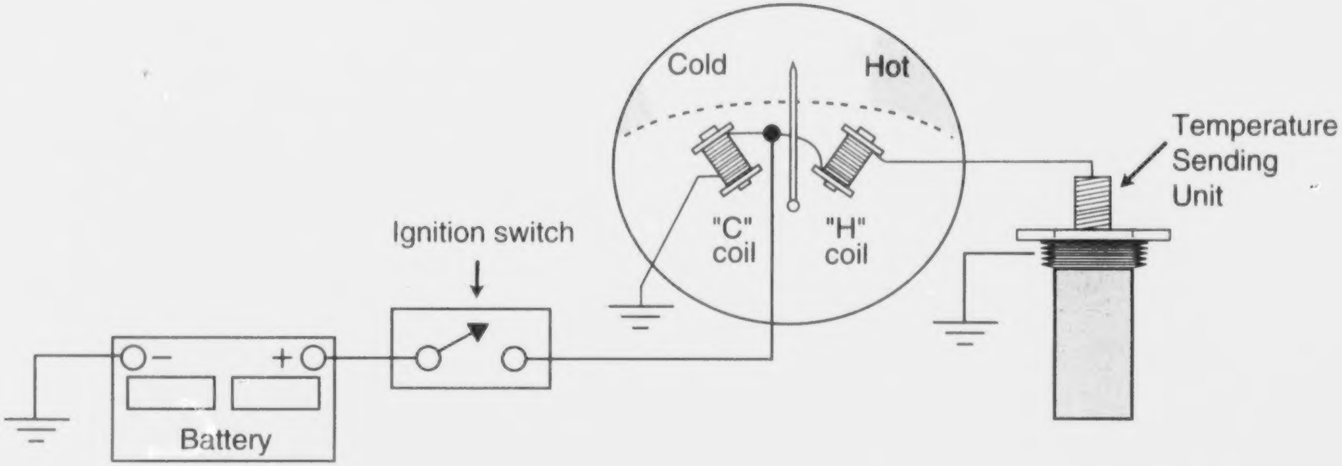
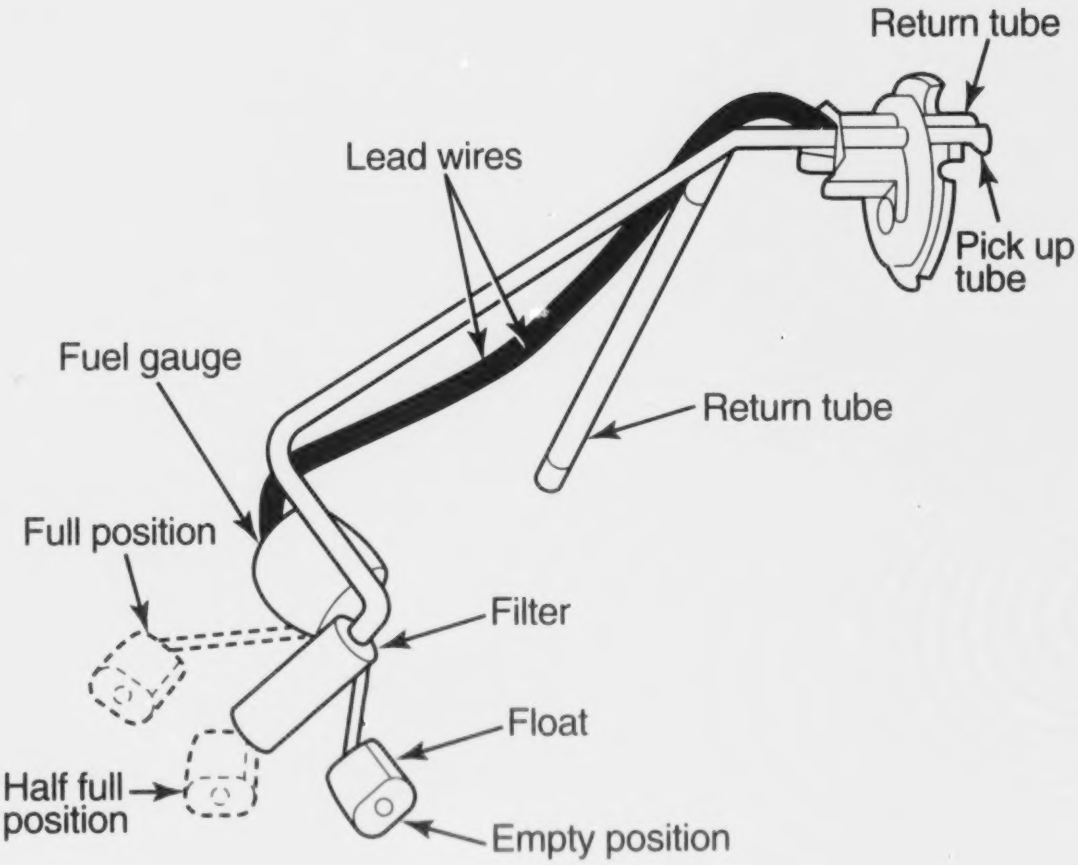
437

Electromagnetic Gauge

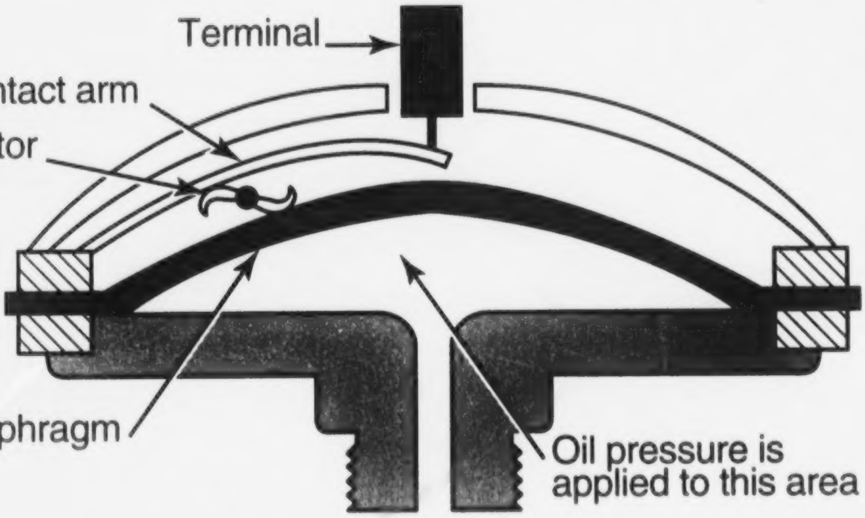

Cold
Hot
"C" coil
"H" coil
Temperature Sending Unit
Ignition switch
–
+
Battery

Fuel Gauge Sending Unit Using a Mechanical Variable Resistor (Potentiometer)

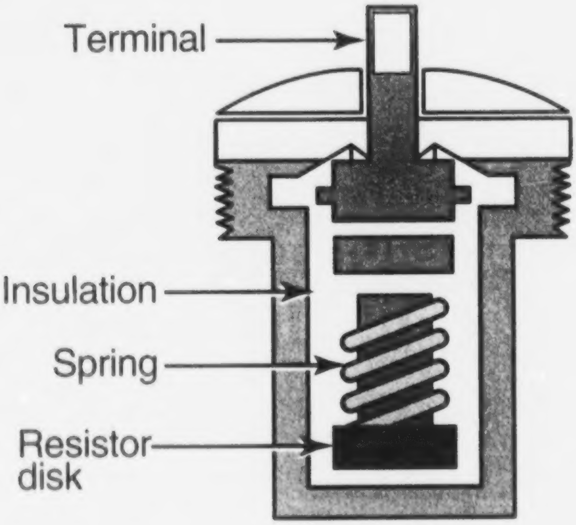

Return tube
Lead wires
Pick up tube
Fuel gauge
Return tube
Full position
Filter
Float
Half full position
Empty position

Used with permission of Ford Motor Co.

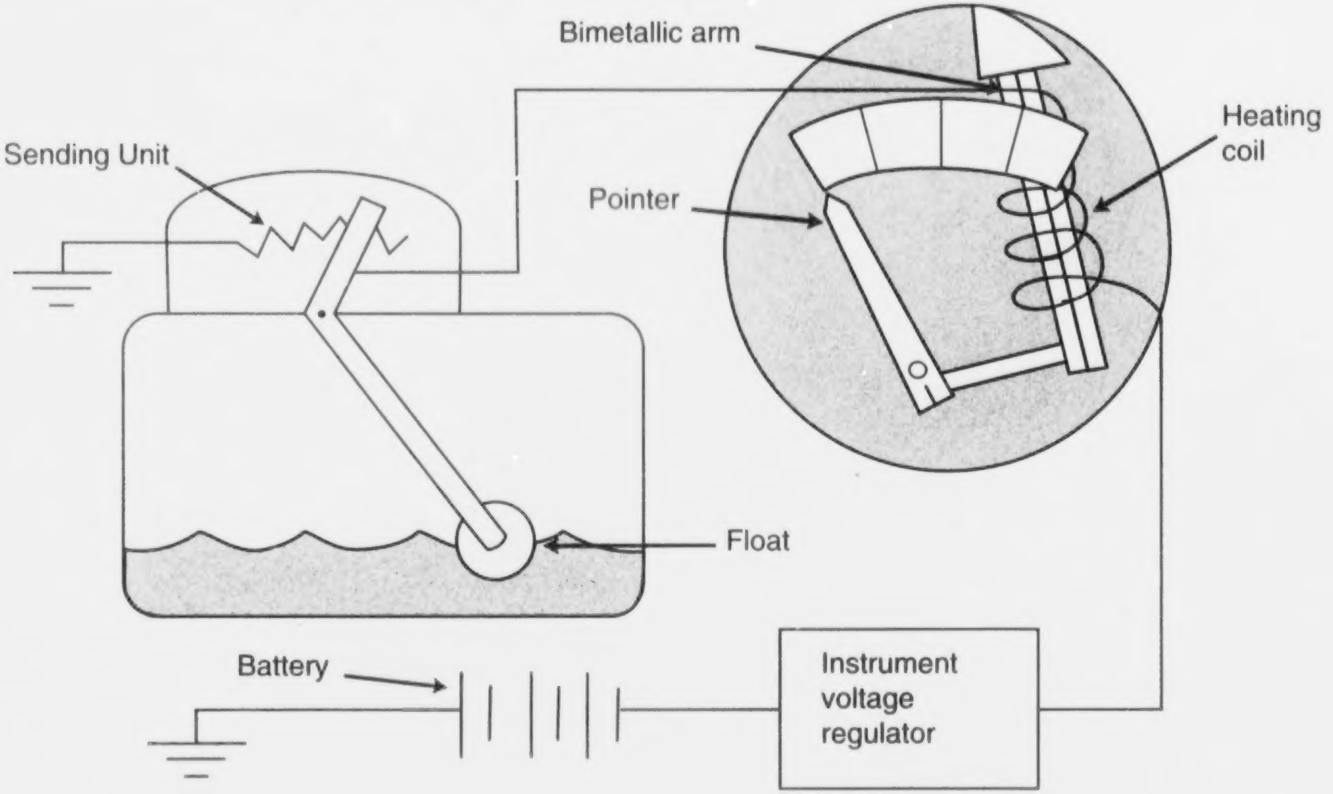
Oil Pressure Sending Unit with Piesoresistive Sensor


Terminal
Contact arm
Variable resistor
Diaphragm
Oil pressure is applied to this area

Engine Temperature Sending Unit with Thermistor

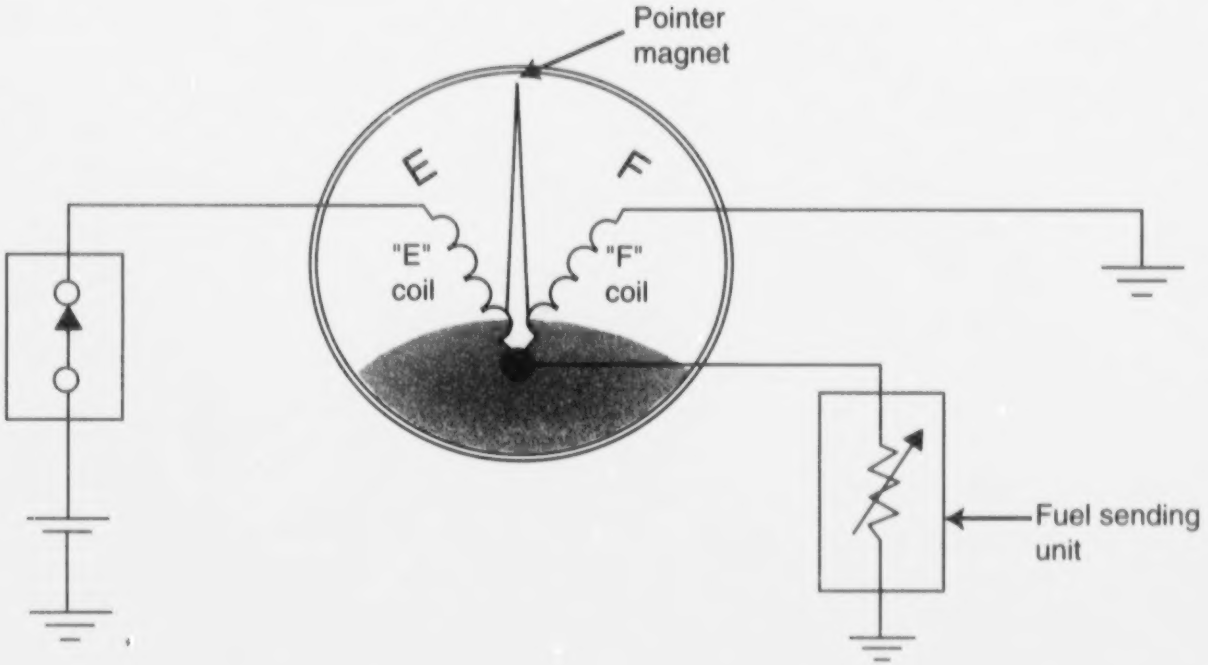

Terminal
Insulation
Spring
Resistor disk

Bimetallic Gauge Circuit


Bimetallic arm
Heating coil
Sending Unit
Pointer
Float
Battery
Instrument voltage regulator

Used with permission of Daimler/Chrysler Corp.

Electromagnetic Two-Coil Gauge Circuit


Pointer magnet
E
F
"E" coil
"F" coil
Fuel sending unit

445

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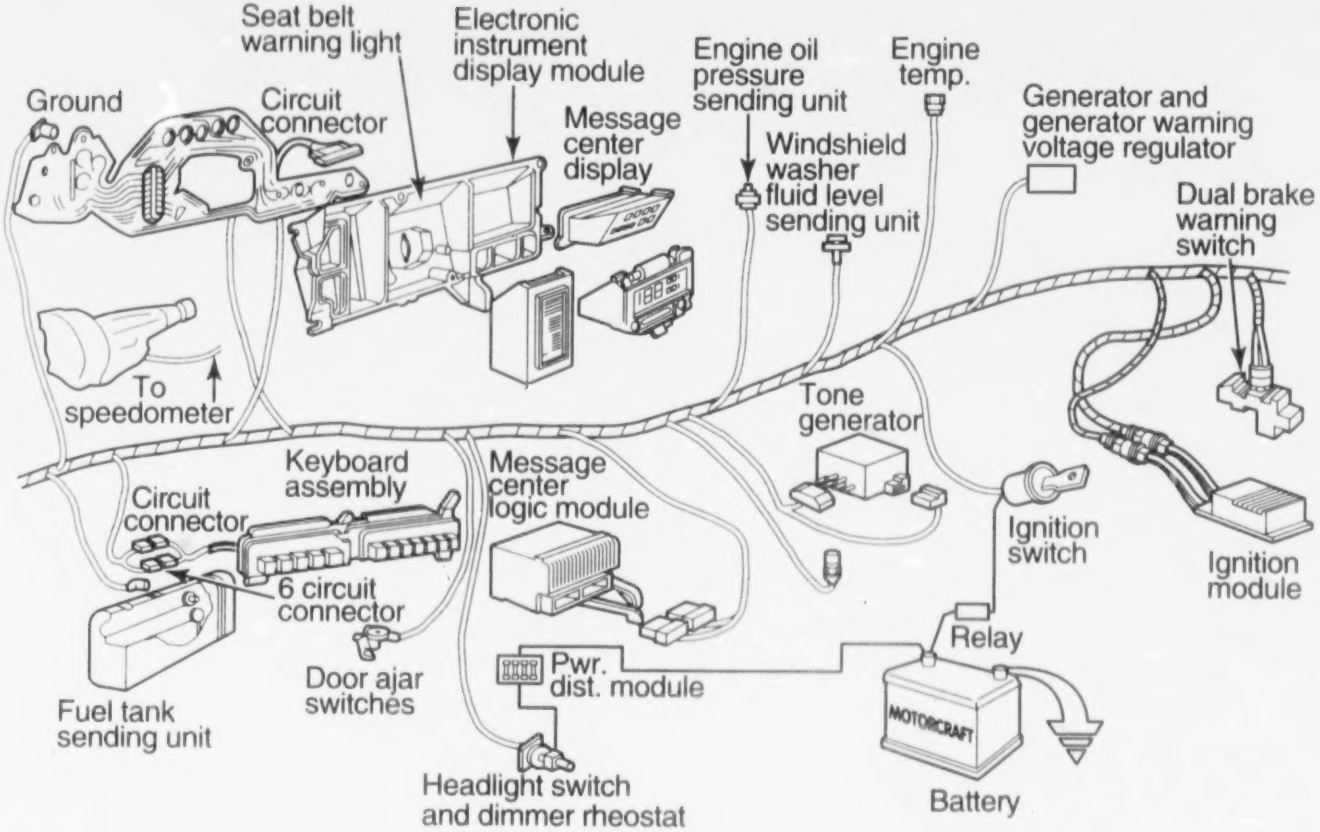
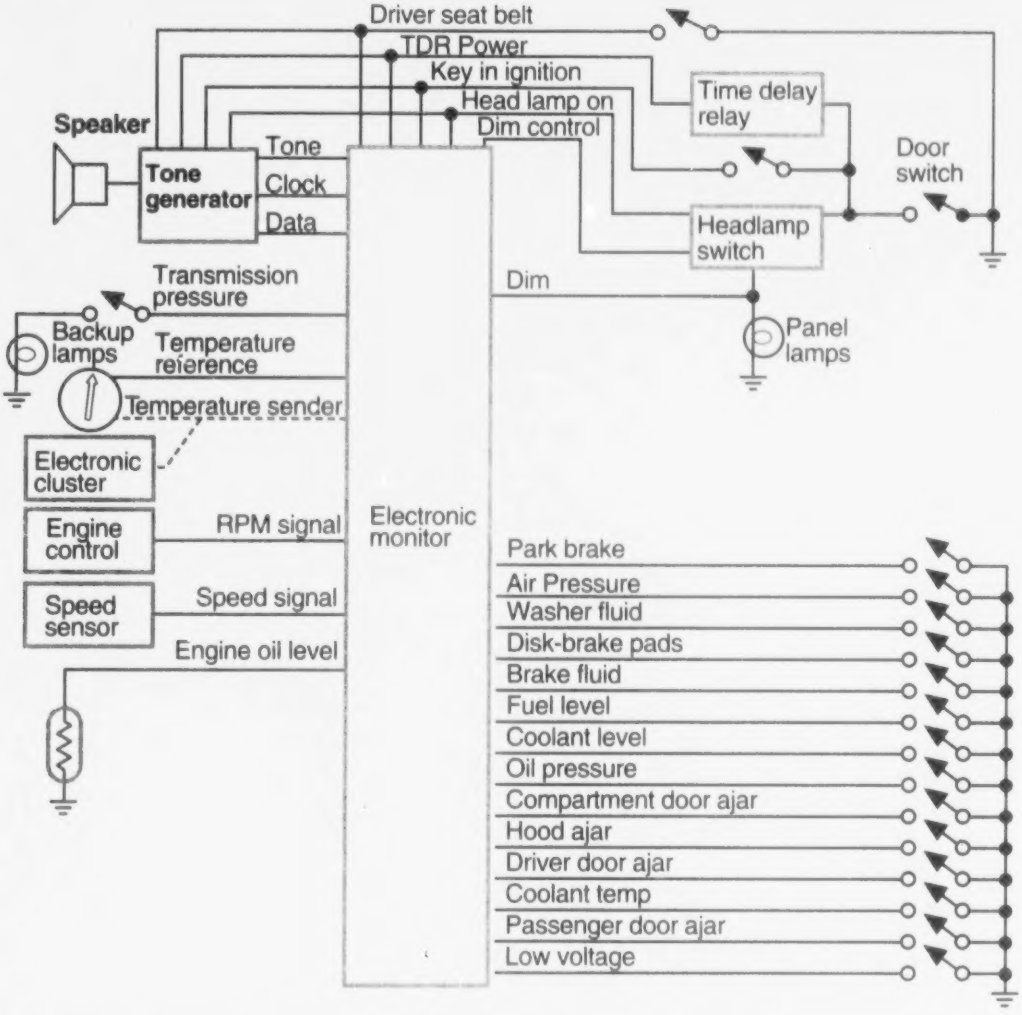
Electronic Instrument Cluster, Warning Light Indicator Light, and Driver Information Circuit


Seat belt warning light
Electronic instrument display module
Ground
Circuit connector
Message center display
Engine oil pressure sending unit
Engine temp.
Windshield washer fluid level sending unit
Generator and generator warning voltage regulator
Dual brake warning switch
To speedometer
Tone generator
Keyboard assembly
Circuit connector
Message center logic module
6 circuit connector
Ignition switch
Ignition module
Relay
Door ajar switches
Pwr. dist. module
MOTORCRAFT
Fuel tank sending unit
Headlight switch and dimmer rheostat
Battery

Used with permission of Ford Motor Co.

Audible Warning Device Circuit


Driver seat belt
TDR Power
Key in ignition
Head lamp on
Dim control
Speaker
Tone generator
Tone
Clock
Data
Time delay relay
Door switch
Headlamp switch
Dim
Panel lamps
Transmission pressure
Backup lamps
Temperature reference
Temperature sender
Electronic cluster
Engine control
RPM signal
Speed sensor
Speed signal
Engine oil level
Electronic monitor
Park brake
Air Pressure
Washer fluid
Disk-brake pads
Brake fluid
Fuel level
Coolant level
Oil pressure
Compartment door ajar
Hood ajar
Driver door ajar
Coolant temp
Passenger door ajar
Low voltage

Used with permission of DaimlerChrysler Corp.

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TM 9

Unit 10 Related Electrical Components

Unit Contents

Teacher Components

Teacher Page

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7—Inspect, Test, Repair, and Replace the Components of an Engine Block Heater 10–77

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Parts of a Horn Circuit (Objective 1)
  TM 2—Parts of a Wiper Circuit (Objectives 2 and 3)
  TM 3—Parts of a Washer Circuit (Objectives 4 and 5)
  TM 4—Sleeper Heater and Air Conditioner Assembly (Objective 6)
  TM 5—Sleeper Heater and Air Conditioner Circuit (Objective 7)
  TM 6—Components of an Expansion Valve Type A/C System (Objective 8)
  TM 7—Typical A/C Electrical Circuit (Objective 9)
  TM 8—Engine Block Heater Elements (Objective 10)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

Suggested Activities

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- As each objective is discussed, show students where parts are located on the vehicle and how they can access those parts.
- Demonstrate how to remove a steering wheel using a wheel puller.
- Re-emphasize the need to consult the manufacturer's procedures for disabling the airbag system prior to troubleshooting or repairing horn components.
- Have students locate three web sites and research appropriate and inappropriate fluids to use in the windshield washer system.
  - Have students write a three-paragraph report on what they've learned about windshield washer fluids. The first paragraph should include the reasons why certain fluids should not be used. The second paragraph should list the advantages and disadvantages of specific fluids. The third paragraph should contain their recommendations concerning which fluid is best and why they think so.
- Show students the differences between heating systems that are electronically operated and ones that are manually operated.
- Show students, on vehicles, the differences between air conditioners that use the expansion valve system and air conditioners that use the orifice tube system.
- Demonstrate how to remove a heater core from the vehicle and how to test one for leaks.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

Suggested Activities

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Advance Tech Student Manual. *Mechanical and Electrical Repair.* I-CAR Education Foundation, 1995
- Derato, Frank C. *Automotive Electrical and Electronic Systems Shop Manual.* Glencoe/McGraw-Hill, 1990.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual.* Albany, New York: Delmar Publishers, 1997.
- Hollembeak, Barry. *Today's Technician: Shop Manual for Automotive Electricity and Electronics.* Albany, New York: Delmar Publishers, 1994.
- Johnson, Larry, and William King. *Automotive Encyclopedia.* Westerville, Ohio: Goodheart-Willcox, 1983.
- Knowles, Don. *Today's Technician: Classroom Manual Automotive Computer Systems.* Albany, New York: Delmar Publishers, 1995.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems)*, Albany, NY: Delmar Publishers, 2000.
- Chapman, Norm. *Principles of Electricity and Electronics for the Automotive Technician*, 1st ed. Albany, NY: Delmar Publishers, 2000.
- Hollembeak, Barry. *Automotive Electricity, Electronics and Computer Controls*, 1st ed. Albany, NY: Delmar Publishers, 1999.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics*, Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Diagnose the Cause of Horn Problems

1. A
2. C
3. A
4. C
5. C
6. D
7. A
8. D
9. C
10. C

Assignment Sheet 2

Diagnose the Cause of Wiper Problems

1. A
2. A
3. C
4. C
5. C
6. A
7. D
8. D
9. A
10. A

Assignment Sheet 3

Diagnose the Cause of Windshield Washer Problems

1. B
2. D
3. D
4. B
5. A

Assignment Sheet 4

Diagnose the Cause of Heater Problems

1. A
2. B
3. C
4. C

Assignment Sheet 5

Diagnose the Cause of Air Conditioning Problems

1. B
2. A
3. A
4. B
5. A
6. C
7. A
8. A
9. B
10. C

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the names of the parts of a horn circuit to descriptions of their functions. Write the correct number in the blank.

1. Connector
2. Fuse
3. Fusible link
4. Ground circuit
5. Horn assembly
6. Horn-button switch
7. Relay
8. Wiring

_____ a. Protects components from excessive current flow and short circuits

_____ b. Controls current by rapidly switching current on and off

_____ c. Plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

_____ d. Converts electrical energy into mechanical energy to produce sound

_____ e. Controls current flow to horn assembly to complete the circuit to ground

_____ f. Protects components of the circuit from short circuits and current overloads

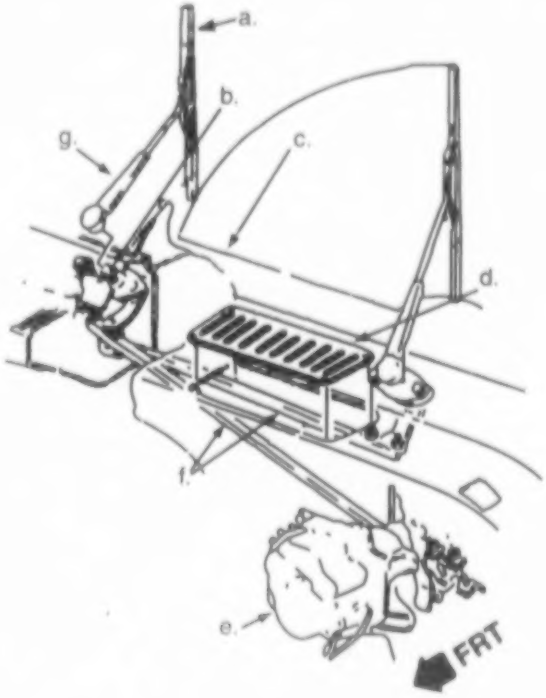
_____ g. Connects components to the battery and/or each other

_____ h. A common negative connection that provides a path for electricity to return to its source after reaching its intended load and circuit.

Written Test

Objective 2

Label the parts of a horn circuit. Write the correct name of the part in the space provided.



a. ________________________________

b. ________________________________

c. ________________________________

d. ________________________________

e. ________________________________

f. ________________________________

g. ________________________________

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Written Test

Objective 3

Match the names of the parts of a wiper circuit to descriptions of their functions. Write the correct number in the blank.

1. Intermittent wiper circuit
2. Wiper blade
3. Wiper linkage
4. Wiper motor
5. Wiper switch

_____ a. Transfers the motion from the wiper motor to complete the circuit to ground

_____ b. Rubber piece on an arm that moves back and forth over the windshield removing water, snow, dirt, or other foreign matter

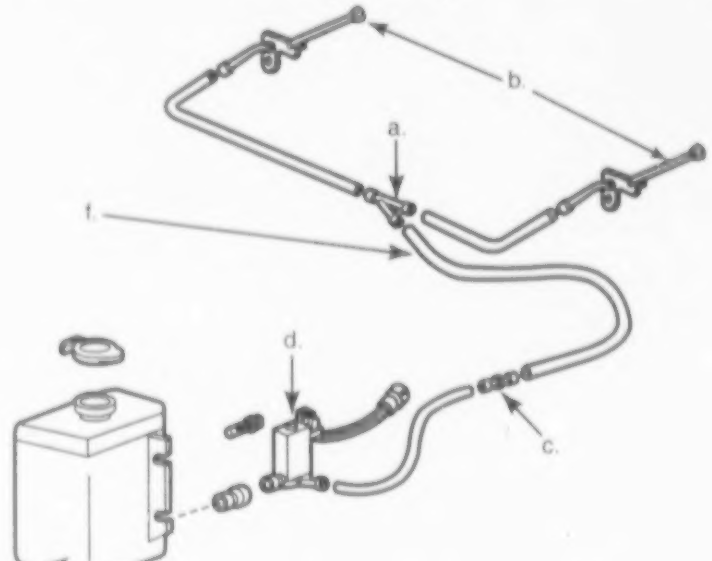
_____ c. Controls current flow to the wiper motor to complete the circuit to ground

_____ d. Contains a solid-state module which opens and closes the ground circuit on the low-speed relay winding of the wiper motor

_____ e. Changes electrical energy into mechanical energy

Objective 4

Label the parts of a windshield washer circuit. Write the correct name of the part in the space provided.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

Written Test

Objective 5

Match the names of the parts of a windshield washer circuit to descriptions of their functions. Write the correct number in the blank.

1. Nozzle
2. Rubber or plastic hose
3. Washer pump
4. Wiper switch

_____ a. Controls the current flow to the wiper motor to complete the circuit to ground

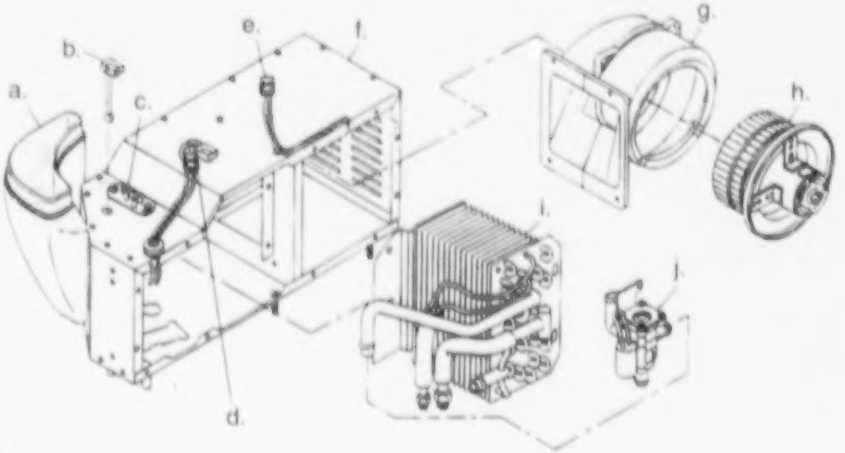
_____ b. Holds washer solution and transport it to the nozzles

_____ c. Forces washer solution onto the windshield in a spray pattern.

_____ d. Displaces solution from the reservoir.

Objective 6

Label the parts of a heater circuit. Write the correct name of the part in the space provided.



Courtesy of Freightliner LLC

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

Objective 7

Match the names of the parts of a heater circuit to the descriptions of their functions. Write the correct number in the blank.

1. Blower control switch
2. Blower motor
3. Circuit breaker
4. Cooling tube
5. Heater, cab/sleeper
6. Resistor block
7. Temperature control module

_____ a. Protects components of the circuit from temporary current overloads

_____ b. Computer unit that maintains a specific temperature automatically inside the cab compartment through employment of numerous temperature sensors

_____ c. Cools the blower motor by circulating air around the motor

_____ d. Converts electrical energy to mechanical energy to operate the blower fan

_____ e. Heat exchanger which obtains heat from the circulated engine coolant at the heater core

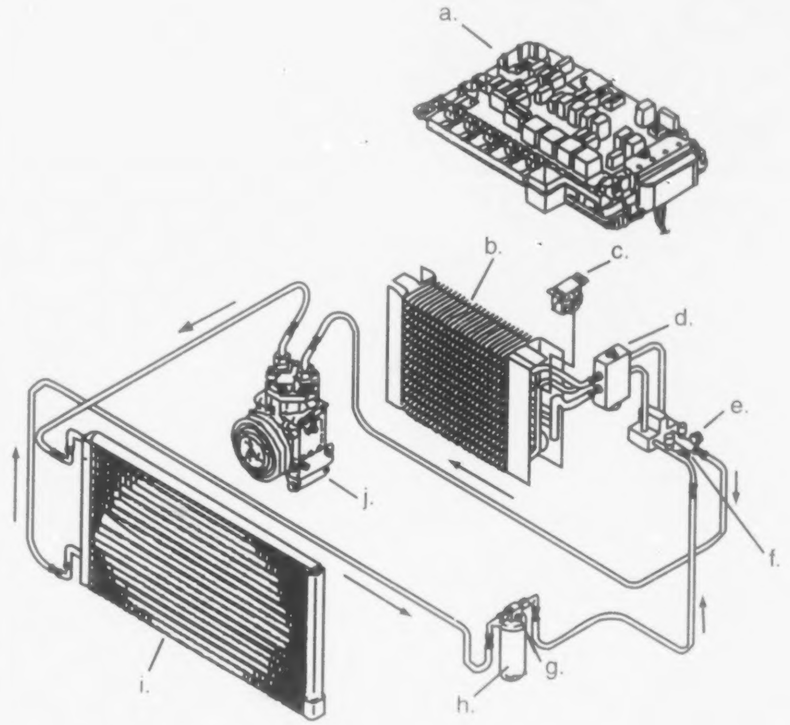
_____ f. Controls current flow to the blower motor which regulates the amount of air delivered through the cab and sleeper vents

_____ g. Used to cause a voltage drop that controls the different speeds of the blower motor

Written Test

Objective 8

Label the major and secondary components of an expansion valve type A/C system. Write the correct name of the component in the space provided.



Courtesy of Freightliner LLC

a. ______________________
f. ______________________
b. ______________________
g. ______________________
c. ______________________
h. ______________________
d. ______________________
i. ______________________
e. ______________________
j. ______________________

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Written Test

Objective 9

Match the names of the parts of an air conditioning circuit to the descriptions of their functions. Definitions continue on the next page.

1. Accumulator
2. Binary switch
3. Blower control switch
4. Circuit breaker
5. Compressor
6. Condenser
7. Cycling pressure switch
8. Evaporator
9. Orifice expansion tube
10. Power distribution module
11. Pressure relief valve
12. Receiver/dryer
13. Resistor block
14. Sight glass
15. Surge diode
16. Thermostatic expansion valve
17. Thermostatic switch

_____ a. Normally located on the receiver/dryer, designed to open to relieve pressure when refrigerant pressure reaches approximately 400 PSI.

_____ b. Removes heat from high-pressure hot vapor coming from the compressor and turns it into high pressure warm liquid

_____ c. Allows technician to detect multiple problems such as system contamination or low refrigerant level

_____ d. Provides low- and high-pressure protection for the system by switching the compressor on or off

_____ e. Used in an expansion valve system, controls refrigerant flow to the evaporator by comparing evaporator pressure and temperature

_____ f. Receives low-pressure, low-temperature liquid refrigerant from the thermostatic expansion valve or orifice tube in the form of spray

_____ g. Used to house relays, circuit breakers, fuses, and other control modules for the control of A/C circuits

_____ h. Used in an orifice tube system, removes moisture and particles from the liquid refrigerant and prevents liquid refrigerant from entering the compressor

_____ i. Removes moisture and particles from the liquid refrigerant, and stores refrigerant until needed in the system

_____ j. Protects components of the circuit from temporary current overloads

_____ k. Senses when a preset temperature is reached in the evaporator and cycles the compressor on and off to prevent the moisture that condenses on the evaporator fins from freezing

____ l. Used to cause a voltage drop that controls the different speeds of the blower motor

____ m. Used on systems with an expansion valve, senses temperature and keeps the evaporator from freezing

____ n. Controls current flow to the blower motor which regulates the amount of air delivered through the cab and sleeper vents

____ o. Used in an orifice tube system, controls refrigerant flow to the evaporator through a fixed orifice and provides low- and high-pressure protection for the system

____ p. Used to protect electronic equipment from voltage spikes

____ q. Draws low-pressure vapor from the evaporator and compresses it into high-pressure vapor enabling the condenser to change the vapor back into liquid

Objective 10

Distinguish between types of engine block heaters by matching the type of engine block heater to the description of its operation. Write the correct number in the blank.

1. Immersion block heater
2. Circulating tank heater
3. Diesel-fire coolant heater

____ a. Ignited by a glow pin, a flame is established and the glow pin shuts off. An integrated water pump circulates the water over the heat exchanger and heats the coolant, then circulates it through the engine block

____ b. Heats coolant at the bottom of the engine block causing the heated coolant to rise where it is circulated back into the top of the block.

____ c. Installed directly into the engine block, the warmed coolant circulates around the cylinder walls

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 3
b. 7
c. 1
d. 5
e. 6
f. 2
g. 8
h. 4

Objective 2

a. Blade
b. Pivot shaft
c. Blade position with motor turned off
d. Ventilator grille
e. Motor
f. Linkage
g. Wiper arm

Objective 3

a. 3
b. 2
c. 5
d. 1
e. 4

Objective 4

a. Connector
b. Washer nozzles
c. Connector
d. Washer and motor pump
e. Washer fluid solution reservoir
f. Rubber or plastic hose

Objective 5

a. 4
b. 2
c. 1
d. 3

Objective 6

a. Discharge air duct
b. Sensor
c. Resistor block assembly
d. Water supply solenoid valve electrical connector
e. Blower motor electrical assembly
f. Housing assembly
g. Blower motor housing
h. Blower motor assembly
i. Evaporator/Heater core assembly
j. Water supply solenoid valve

Answers to Written Test

Objective 7

a.	3	e.	5
b.	7	f.	1
c	4	g.	6
d.	2		

Objective 8

a. Power distribution module
b. Evaporator
c. Thermostatic switch
d. Thermostatic expansion valve
e. Sleeper lowside return connection
f. Sleeper highside return connection
g. Sight glass
h. Receiver/dryer
i. Condenser
j. Compressor

Objective 9

a.	11	g.	10	m.	17
b.	6	h.	1	n.	3
c.	14	i.	12	o.	9
d.	2	j.	4	p.	15
e.	16	k.	7	q.	5
f.	8	l.	13		

Objective 10

a.	3
b.	2
c.	1

Unit 10 — Related Electrical Components

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objective 1.

☐ 4. **Read** Student Supplement 1, "How a Horn Works", and Student Supplement 2, "Diagnosing Horn Problems".

☐ 5. **Do** Assignment Sheet 1, "Diagnose the Cause of Horn Problems".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat steps 3, 4, and 5.

☐ 7. **Do** Job Sheet 1, "Inspect, Test, Repair, and Replace the Components of a Horn Circuit".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat step 7.

☐ 9. **Study** Information Sheet, Objectives 2 and 3.

☐ 10. **Read** Student Supplement 3, "How a Wiper Operates", and Student Supplement 4, "Diagnosing Windshield Wiper Problems".

☐ 11. **Do** Assignment Sheet 2, "Diagnose the Cause of Wiper Problems".

Learning Activities Sheet

☐ 12. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, repeat steps 9, 10, and 11.

☐ 13. **Do** Job Sheet 2, "Inspect, Test, and Replace the Components of Wiper Circuits".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat step 13.

☐ 15. **Do** Job Sheet 3, "Inspect, Test, Repair, and Replace Intermittent (Pulsing) Wiper Controls".

☐ 16. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat step 15.

☐ 17. **Study** Information Sheet, Objectives 4 and 5.

☐ 18. **Read** Student Supplement 5, "How a Washer System Operates".

☐ 19. **Do** Assignment Sheet 3, "Diagnose the Cause of Windshield Washer Problems".

☐ 20. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, repeat steps 17, 18, and 19.

☐ 21. **Do** Job Sheet 4, "Inspect, Test, Repair, and Replace the Components of a Windshield Washer Circuit".

☐ 22. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 23. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat step 21.

☐ 23. **Study** Information Sheet, Objectives 6 and 7.

☐ 24. **Read** Student Supplement 6, “How a Heating System Operates”.

☐ 25. **Do** Assignment Sheet 4, “Diagnose the Cause of Heater Problems”.

☐ 26. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, repeat steps 23, 24, and 25.

☐ 27. **Do** Job Sheet 5, “Inspect, Test, Repair, and Replace the Components of a Heater Circuit”.

☐ 28. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 29. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat step 27.

☐ 29. **Study** Information Sheet, Objectives 8 and 9.

☐ 30. **Read** Student Supplement 7, “How an Air Conditioning System Operates”.

☐ 31. **Do** Assignment Sheet 5, “Diagnose the Cause of Air Conditioning Problems”.

☐ 32. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 33. If the evaluation is not satisfactory, repeat steps 29, 30, and 31.

☐ 33. **Do** Job Sheet 6, “Inspect, Test, Repair, and Replace the Components of an Air Conditioning Circuit”.

☐ 34. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 35. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat step 33.

☐ 35. **Study** Information Sheet, Objective 10.

Learning Activities Sheet

☐ 36. **Do** Job Sheet 7, "Inspect, Test, Repair, and Replace the Components of an Engine Block Heater".

☐ 37. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 38. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat step 36.

☐ 38. **Check** With instructor for any additional assignments to be completed.

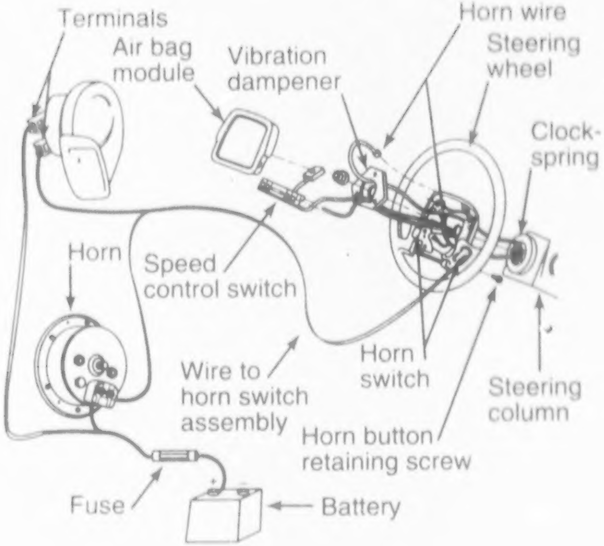
☐ 39. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

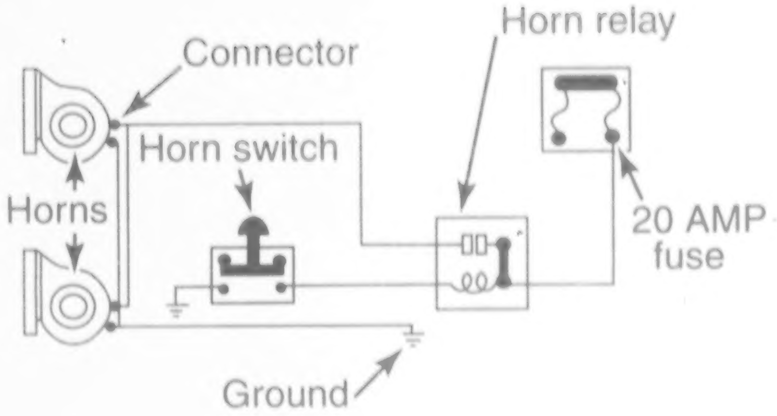
☐ 40. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

*Permission to duplicate this form is granted.

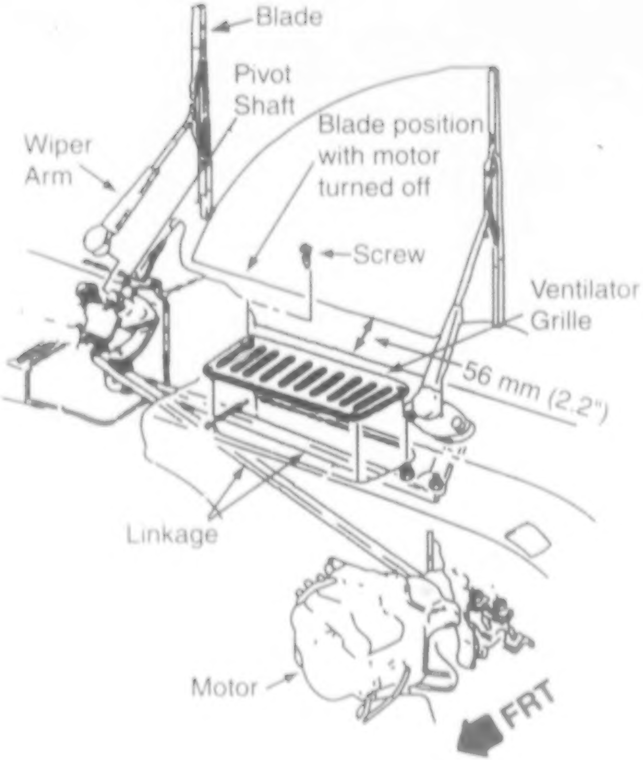
4.0

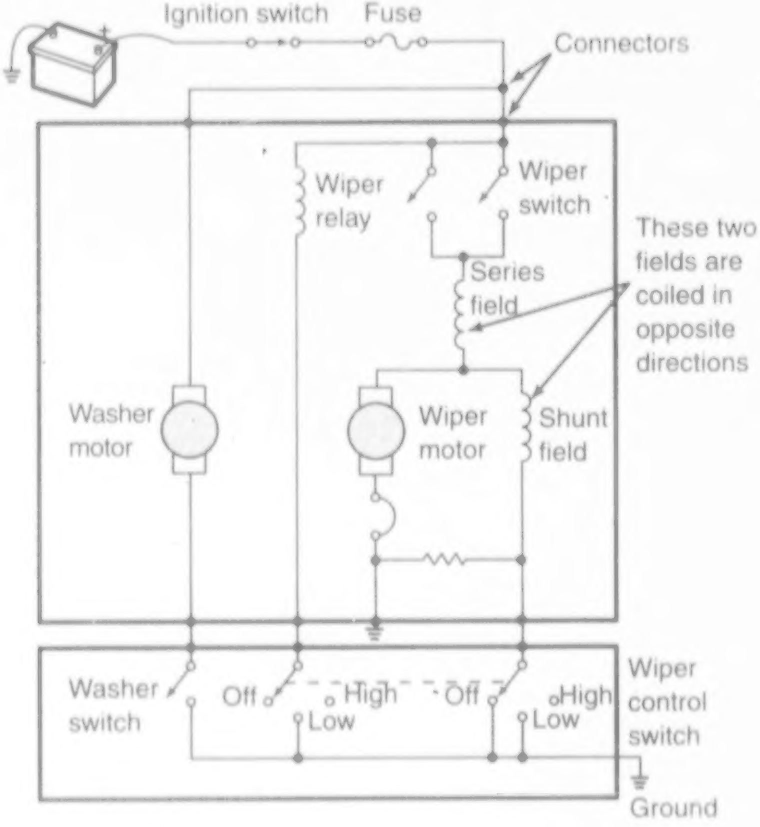
Parts of a Horn Circuit


Terminals
Air bag module
Vibration dampener
Horn wire
Steering wheel
Clock-spring
Horn
Speed control switch
Wire to horn switch assembly
Horn switch
Steering column
Horn button retaining screw
Fuse
Battery

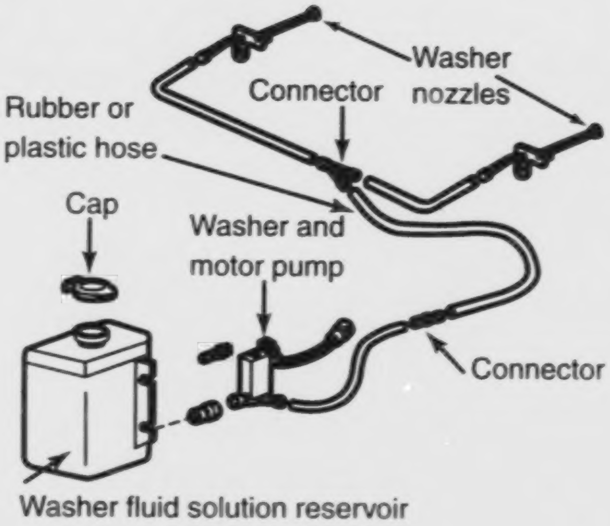

Horn relay
Connector
Horn switch
Horns
20 AMP fuse
Ground

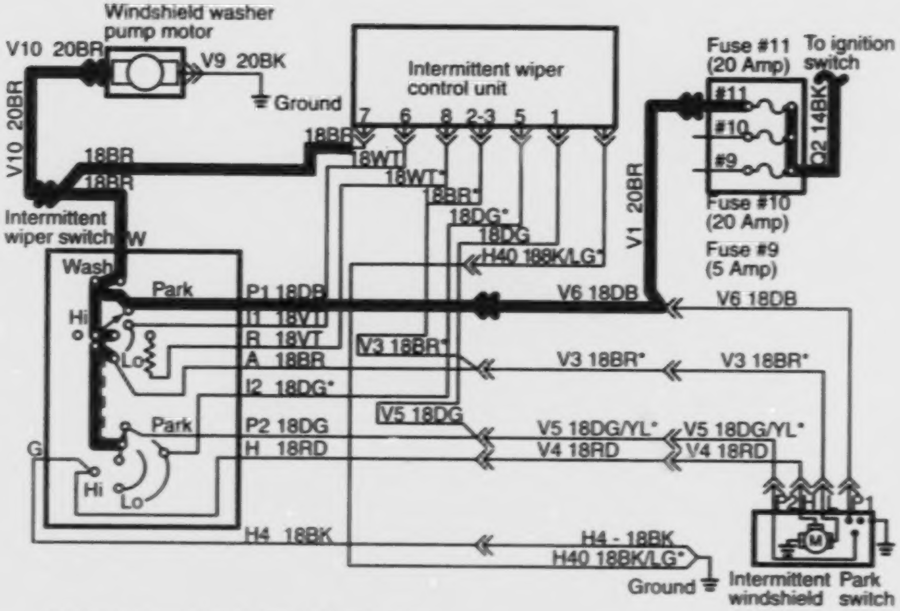
Parts of a Wiper Circuit


Blade
Pivot Shaft
Wiper Arm
Blade position with motor turned off
Screw
Ventilator Grille
56 mm (2.2")
Linkage
Motor
FRT


Ignition switch
Fuse
Connectors
Wiper relay
Wiper switch
These two fields are coiled in opposite directions
Series field
Washer motor
Wiper motor
Shunt field
Washer switch
Off
High
Low
Off
High
Low
Wiper control switch
Ground

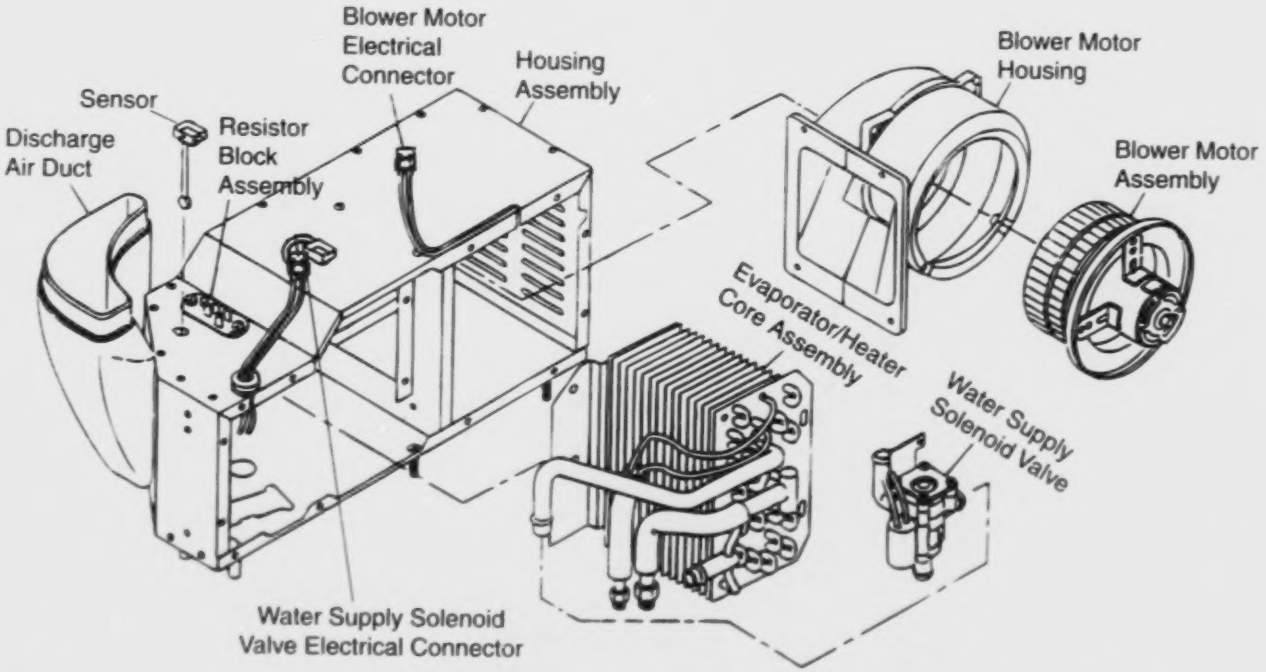
Parts of a Washer Circuit


Washer nozzles
Connector
Rubber or plastic hose
Cap
Washer and motor pump
Connector
Washer fluid solution reservoir


Windshield washer pump motor
V10 20BR
V9 20BK
Ground
Intermittent wiper control unit
7
6
8
2-3
5
1
Fuse #11 (20 Amp)
To ignition switch
#11
#10
#9
Q2 14BK
Fuse #10 (20 Amp)
Fuse #9 (5 Amp)
V10 20BR
18BR
18BR
18BR
18WT
18WT*
18BR*
18DG*
18DG
H40 18BK/LG*
V1 20BR
Intermittent wiper switch
W
Wash
Park
Hi
Lo
P1 18DB
I1 18VT
R 18VT
A 18BR
I2 18DG*
P2 18DG
H 18RD
Park
G
Hi
Lo
V6 18DB
V6 18DB
V3 18BR*
V3 18BR*
V3 18BR*
V5 18DG
V5 18DG/YL*
V5 18DG/YL*
V4 18RD
V4 18RD
H4 18BK
H4 - 18BK
H40 18BK/LG*
Ground
P2
H
I
P1
M
Intermittent windshield
Park switch

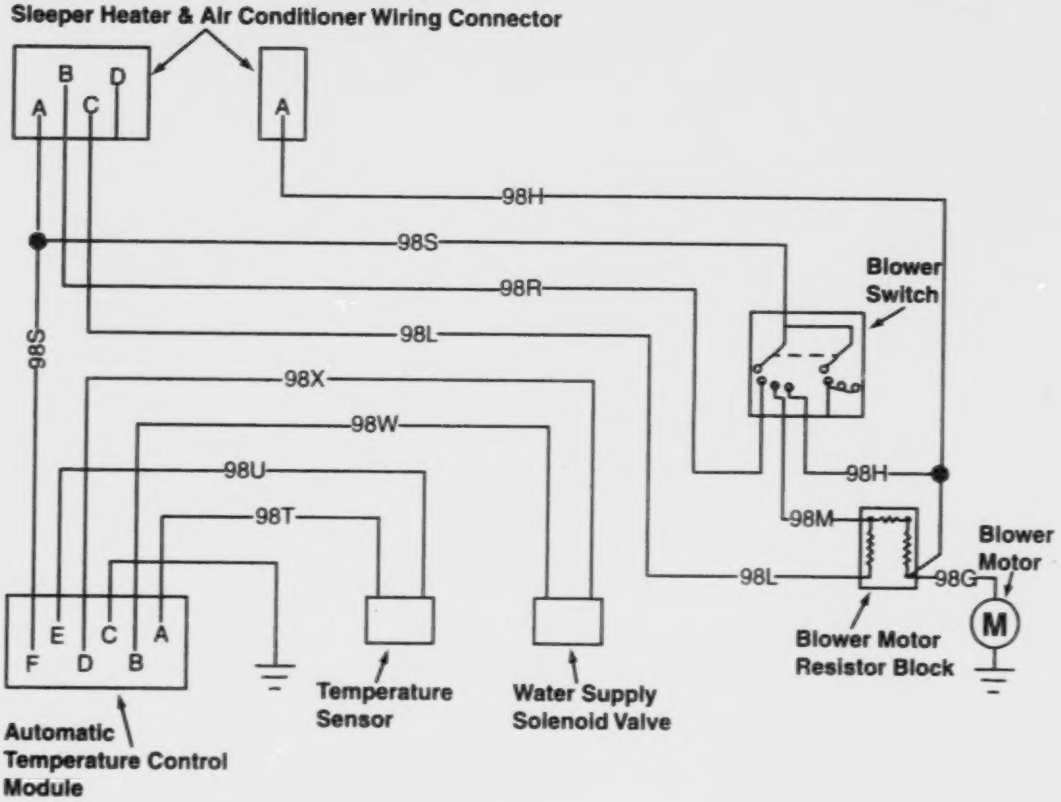
Ued with permission of DaimlerChrysler Corp.

Sleeper Heater and Air Conditioner Assembly


Blower Motor Electrical Connector
Housing Assembly
Blower Motor Housing
Sensor
Resistor Block Assembly
Discharge Air Duct
Blower Motor Assembly
Evaporator/Heater Core Assembly
Water Supply Solenoid Valve
Water Supply Solenoid Valve Electrical Connector

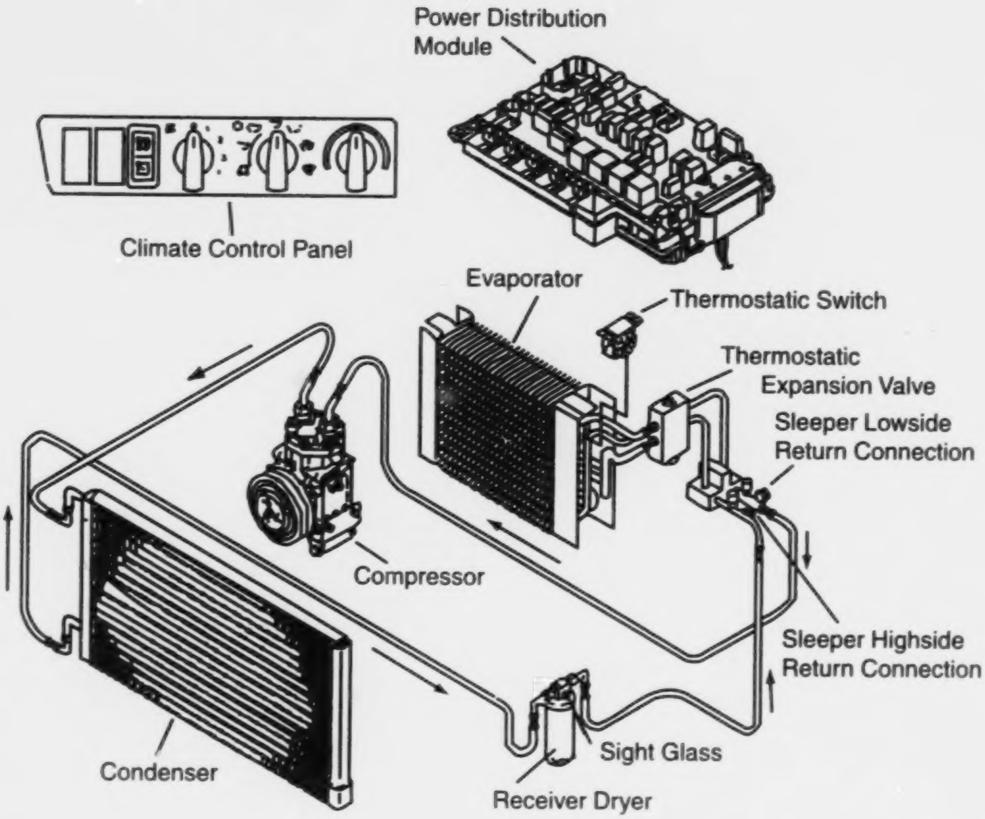
Courtesy of Freightliner LLC

Sleeper Heater and Air Conditioner Circuit


Sleeper Heater & Air Conditioner Wiring Connector
A
B
C
D
A
98H
98S
98R
98L
98S
98X
98W
98U
98T
Blower Switch
98H
98M
98L
98G
Blower Motor
M
Blower Motor Resistor Block
E
C
A
F
D
B
Temperature Sensor
Water Supply Solenoid Valve
Automatic Temperature Control Module

Courtesy of Freightliner LLC

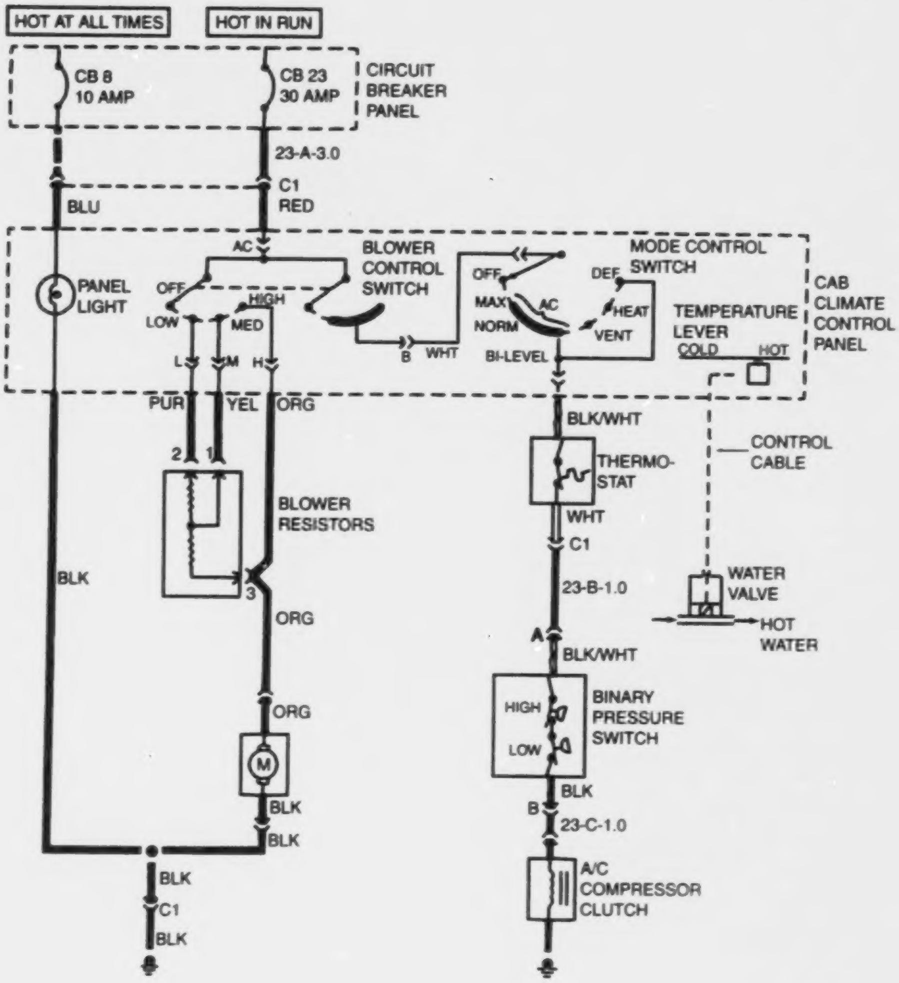
Components of an Expansion Valve Type A/C System


Power Distribution Module
Climate Control Panel
Evaporator
Thermostatic Switch
Thermostatic Expansion Valve
Sleeper Lowside Return Connection
Compressor
Sleeper Highside Return Connection
Condenser
Sight Glass
Receiver Dryer

Courtesy of Freightliner LLC

TM 6

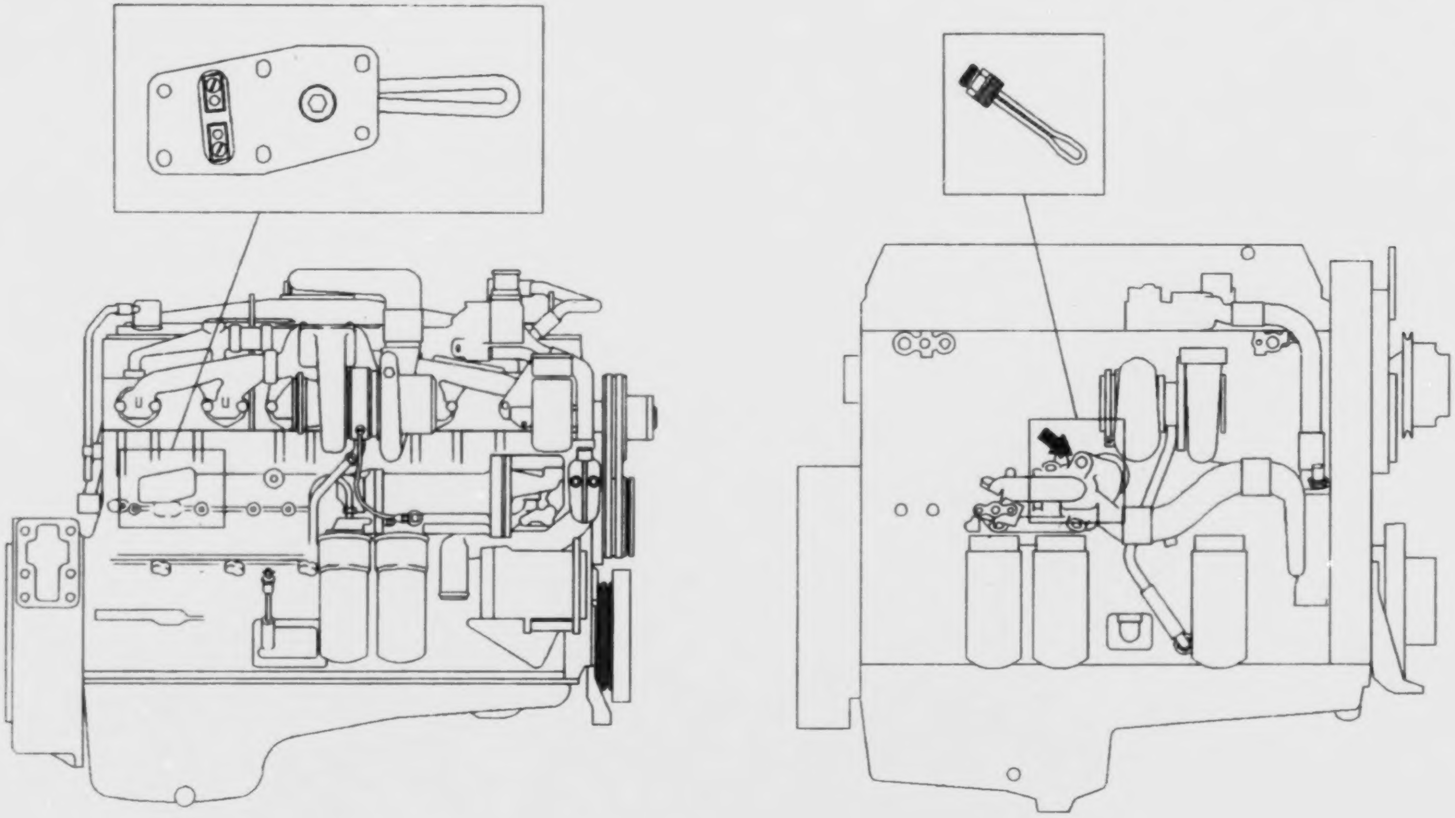
Typical A/C Electrical Circuit


HOT AT ALL TIMES
HOT IN RUN
CB 8
10 AMP
CB 23
30 AMP
CIRCUIT
BREAKER
PANEL
23-A-3.0
C1
RED
BLU
AC
BLOWER
CONTROL
SWITCH
PANEL
LIGHT
OFF
HIGH
LOW
MED
L
M
H
PUR
YEL
ORG
B
WHT
MODE CONTROL
SWITCH
OFF
DEF
MAX
AC
HEAT
NORM
VENT
BI-LEVEL
TEMPERATURE
LEVER
COLD
HOT
CAB
CLIMATE
CONTROL
PANEL
BLK/WHT
THERMO-
STAT
CONTROL
CABLE
2
1
BLOWER
RESISTORS
3
BLK
ORG
ORG
M
BLK
BLK
WHT
C1
23-B-1.0
WATER
VALVE
HOT
WATER
A
BLK/WHT
HIGH
LOW
BINARY
PRESSURE
SWITCH
BLK
B
23-C-1.0
A/C
COMPRESSOR
CLUTCH
BLK
C1
BLK

Courtesy of Mack Trucks Inc.

TM 7

Engine Block Heater Elements



Courtesy of Freightliner LLC

Miscellaneous Electrical Accessories

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Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Parts of a Power Window (Objectives 1 and 2)
TM 2—Parts of a Power Window (Continued) (Objectives 1 and 2)
TM 3—Parts of a Power Window (Continued) (Objectives 1 and 2)
TM 4—Mekra Mirror (Objective 3)
TM 5—Parts of an Electric Door Lock (Objectives 4 and 5)
TM 6—Parts of a Keyless and Remote Lock/Unlock Device (Objectives 6 and 7)
TM 7—Parts of an Anti-Theft System (Objective 8)
TM 8—Parts of a Sound System (Objectives 9 and 10)
TM 9—Parts of an Airbag System (Objective 11)
TM 10—Parts of an Airbag System (Continued) (Objective 12)
TM 11—Seat Restraint System (Objective 12)

Suggested Activities

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- As each objective is discussed, show students where parts are located on the vehicle and how to access those parts.
- Demonstrate power window operation with the door panel removed and show students how the different parts interact with each other.
- Disassemble a mirror to show students how the heating grid, lights, and motor are situated within such small confines.
- Demonstrate electric door lock operation with the door panel removed and show students how the different parts interact with each other.
- Reemphasize the importance of following the manufacturer's instructions and warnings prior to troubleshooting an airbag system.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Suggested Activities

Resources Used in Developing This Unit

Print Media

- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Classroom Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Chek-Chart Publications. *Engine Performance Diagnosis and Tune-Up: Shop Manual.* Sunnyvale, CA: Chek-Chart Publications, 1997.
- Denton, Tom. *Automobile Electrical and Electronic Systems.* Warrendale, PA: SAE International, 1995.
- Duffy, James E. *Auto Electricity and Electronics Technology.* Tinley Park, IL: Goodheart-Wilcox Co., 1998.
- Fowler, Richard J. *Electricity: Principles and Applications.* New York: Glencoe, 1994.
- Halderman, James D. *Automotive Electrical and Electronic Systems: A Worktext.* Englewood Cliffs, NJ: Prentice Hall, 1996.
- Halderman, James D. *Diagnosis and Troubleshooting of Automotive Electrical, Electronic, and Computer Systems.* Upper Saddle River, NJ: Prentice Hall, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Classroom Manual.* Albany, NY: Delmar Publishers, 1997.
- Hollembeak, Barry. *Today's Technician: Automotive Electricity and Electronics Shop Manual.* Albany, NY: Delmar Publishers, 1997.
- Mitchell International. *Domestic Cars Service and Repair 1991.* San Diego, CA: Mitchell International, 1991.
- Ribbens, William B. *Understanding Automotive Electronics* (3rd ed.,). Indianapolis, IN: Howard W. Sams & Company, 1998.
- Santini, Al. *Automotive Electricity and Electronics.* Albany, NY: Delmar Publishers, 1997.
- Santini, Al. *Automotive Electricity and Electronics. Instructor's Guide.* Albany, NY: Delmar Publishers, 1997.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series—Medium/Heavy Duty Truck (Electrical and Electronic Systems).* Albany, NY: Delmar Publishers, 2000.
- Chapman, Norm. *Principles of Electricity and Electronics for the Automotive Technician*, 1st ed. Albany, NY: Delmar Publishers, 2000.

Suggested Activities

- Hollembeak, Barry. *Automotive Electricity, Electronics and Computer Controls,* 1st ed. Albany, NY: Delmar Publishers, 1997.
- Norman, Ian, et al. *Heavy Duty Truck Systems*, 3rd ed. Albany, NY: Delmar Publishers, 2001.
- Oun, Sulev. *Medium/Heavy Duty Truck Electricity and Electronics.* Albany, NY: Delmar Publishers, 2001.

Answers to Assignment Sheets

Assignment Sheet 1

Diagnose the Cause of Power Window Problems

1. A
2. C
3. B
4. B
5. A
6. A
7. True
8. False
9. True
10. True

Assignment Sheet 2

Diagnose the Cause of Heated, Lighted, and Electrically Operated Mirror Problems

1. A
2. C
3. B
4. C
5. A

Assignment Sheet 3

Diagnose the Cause of Electric Door Lock Problems

1. C
2. C
3. D
4. A
5. C

Assignment Sheet 4

Diagnose the Cause of Radio Reception Problems

1. A
2. C
3. B
4. D
5. C
6. C
7. D
8. C
9. D
10. C

Assignment Sheet 5

Diagnose the Cause(s) of the Airbag Warning Light Staying On or Flashing

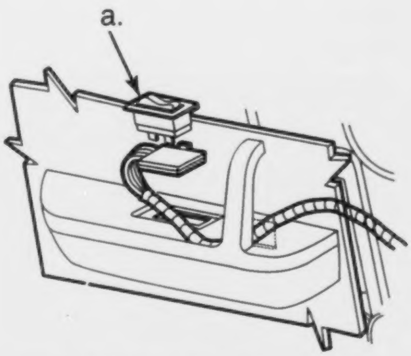
1. B
2. C
3. C
4. D
5. C

Written Test

Name ______________________________

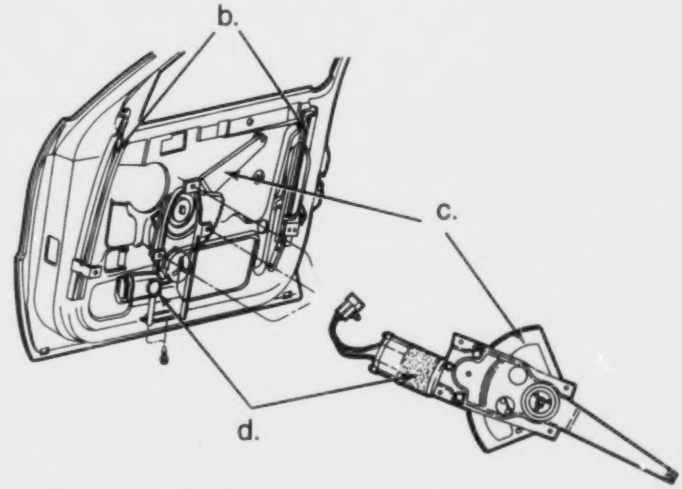
Date ______________________ Score __________

Objective 1 Label the parts of a power window. Write the correct name of the part in the space provided.



Used with permission of DaimlerChrysler Corp.

a. ______________________________



Used with permission of DaimlerChrysler Corp.

b. ______________________________

c. ______________________________

d. ______________________________

Written Test

Objective 2

Match the names of the parts of a power window to descriptions of their functions. Write the correct number in the blank.

1. Glass channel (run)
2. Power window switch
3. Regulator (linkage)
4. Window lift motor

_____ a. Transmits mechanical force from the motor to raise and lower the window depending on the direction of motor rotation

____ b. Moves the drive component of the regulator to reposition the window glass, depending on the polarity of the supply voltage

____ c. Guides the movement of the window in its frame

____ d. Closes the circuit between the power source and the motor and controls the direction of current flow

Objective 3

Match the names of the parts of a heated, lighted, and electrically operated mirror to descriptions of their functions. Write the correct number in the blank.

1. Heated mirror grid (element)
2. Heated mirror switch
3. Motor (drive unit)
4. Power mirror switch

_____ a. When closed, allows voltage to be applied to both mirrors and to the light indicating activation

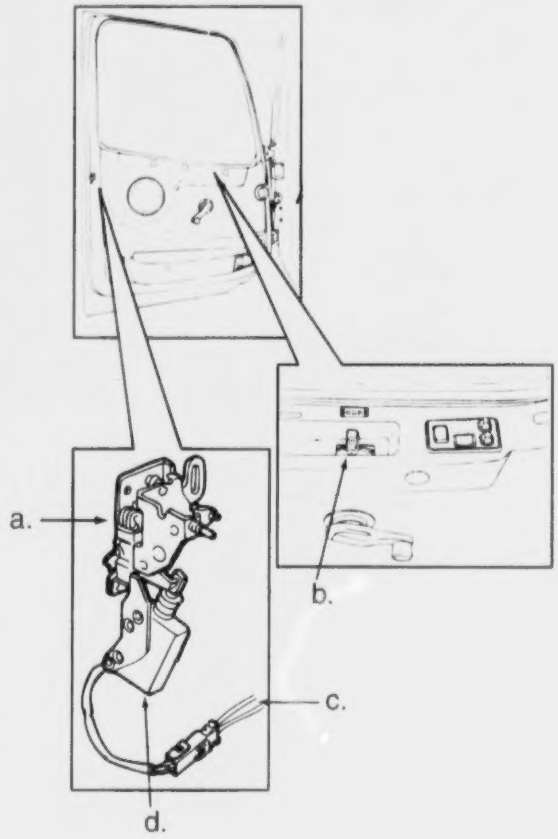
____ b. An integrated unit controlling both the horizontal and vertical movement of the mirror glass

____ c. Heats the surface of the mirror by resisting the flow of current through the grid wires

____ d. Opens or closes the circuit to control the flow of current to the motors and the direction of current flow to determine motor polarity

Objective 4

Label the parts of an electric door lock. Write the correct name of the part in the space provided.



a. ____________________

b. ____________________

c. ____________________

d. ____________________

Written Test

Objective 5

Match the names of the parts of an electrical door lock to descriptions of their functions. Write the correct number in the blank.

1. Actuator
2. Locking mechanism
3. Power door lock relay
4. Power door lock switch

_____ a. When engaged, prevents the door latch from moving so that the door cannot be opened using the exterior (and often also the interior) door handle

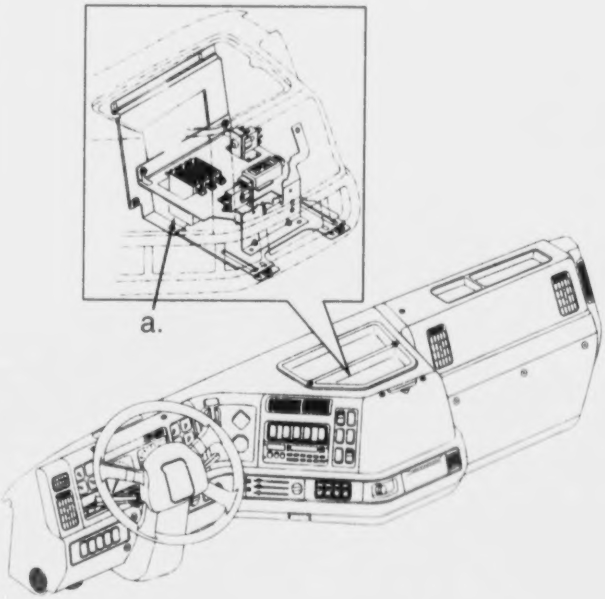
_____ b. Opens or closes the lock-engaging or disengaging circuit to control the flow of current to the lock motors or solenoids

_____ c. Uses an electromagnetic coil to control the direction of current flow to the motors or solenoids and to allow control of multiple circuits from one switch

_____ d. Moves the locking mechanism between the engaged and disengaged positions, using either a motor or a solenoid

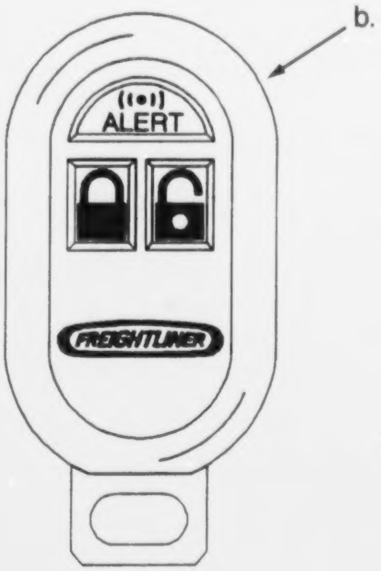
Objective 6

Label the parts of a keyless and remote lock/unlock device. Write the correct name of the part in the space provided. Objective continues on the next page.



a. ______________________________

495



Courtesy of Freightliner LLC

b. ____

Objective 7

Match the names of the parts of a keyless and remote lock/unlock device to descriptions of their functions. Write the correct number in the blank.

1. Control module
2. Power lock circuit
3. Signal input device

_____ a. Engages or disengages the locking mechanism in response to electrical current from the control module

_____ b. Generates a signal on a dedicated frequency and sends it to the control module

_____ c. Receives input signals, validates those signals against stored signal information, and generates an electrical signal to engage or disengage the power lock

Written Test

Objective 8

Match the names of the parts of an anti-theft system to descriptions of their functions. Write the correct number in the blank.

1. Activation controls
2. Security control module
3. Security system relay
4. Security system sensors

_____ a. Arm and disarm the system

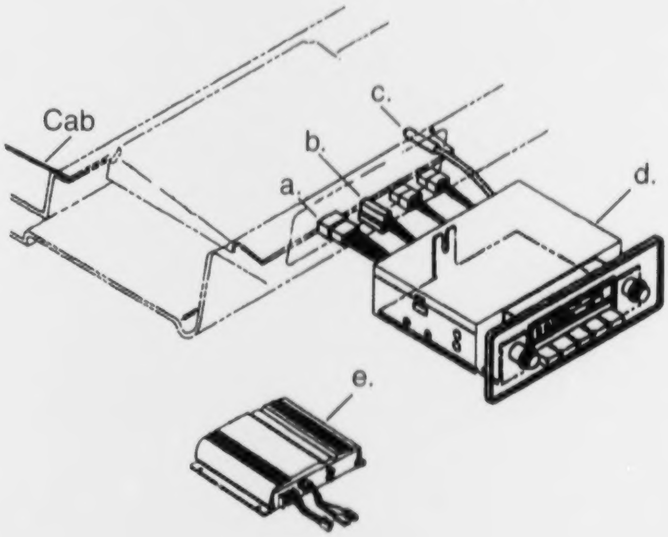
_____ b. Detects a change in electrical condition and activates one or more alarms or engages a disabling system

_____ c. Monitors vehicle components and signals the security control module of an unauthorized intrusion

_____ d. Provides electrical control of system components in response to conditions

Objective 9

Label the parts of a sound system. Write the correct name of the part in the space provided.



Courtesy of Freightliner LLC

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ____

Objective 10

Match the names of the parts of a sound system to descriptions of their functions. Write the correct number in the blank.

1. Amplifier
2. Antenna
3. Antenna lead
4. Control unit
5. Harness lead
6. Speakers

_____ a. Converts the electrical output of the radio into sound using an electromagnet which shifts position in response to the varying electrical current to set up vibrations in a flexible membrane

____ b. Carries radio signals from the antenna to the radio

____ c. Receives AM and FM radio signals from all directions that are broadcast from transmitters

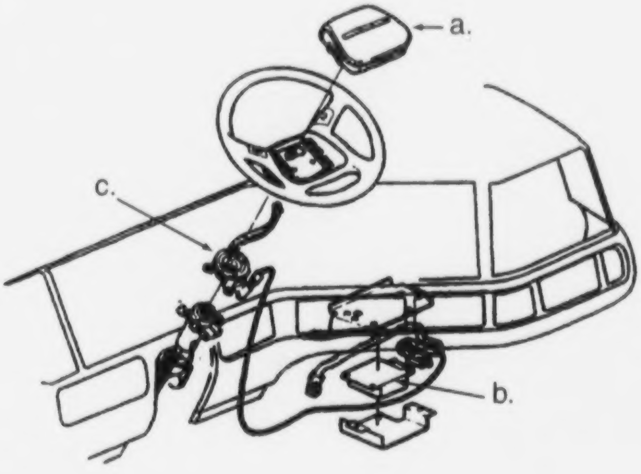
____ d. "Demodulates" the received radio signals and provides for user selection of sound system functions

____ e. Increases the power of received signals from the control unit and outputs them to speakers

____ f. Carries power to the amplifier

Objective 11

Label the parts of an airbag system. Write the correct name of the part in the space provided.



a. ____

b. ____

c. ____

Objective 12

Match the names of the parts of an airbag system to descriptions of their functions. Write the correct number in the blank.

1. Airbag module
2. Clockspring
3. Impact sensors
4. Sensing and diagnostic module
5. Seat restraint system

_____ a. Monitors changes in vehicle velocity and causes current to flow to the inflator when impact signals received exceed values stored in memory

_____ b. An assembly containing an inflatable bag, an inflator and an initiator which act to cushion passengers in a collision

_____ c. Threshold-sensitive switches which react to the severity and direction of an impact by sending a signal to the sensing and diagnostic module

_____ d. Ensures a continuous electrical circuit between the wiring harness and the driver's airbag module

_____ e. Provides additional driver protection in severe frontal collision situations by using gas-cylinder mechanisms mounted at the base of the driver's seat that tighten the seat belts and then lower the seat suspension, moving the seat occupant downward and away from the steering wheel and roof

Objective 13

List what steps you should take to prevent the accidental deployment of an airbag. Write your answers in the blanks.

a. Procedures — ______________________________________

____

b. Wear — ____

____

c. De-energize — _____________________________________

____

d. Drop, strike, or jar — _______________________________

____

e. Pointing away — ___________________________________

f. Wires —

g. Faces away —

h. Disarming —

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1	a.	Power window switch
	b.	Glass channel or run
	c.	Regulator
	d.	Window lift motor
Objective 2	a.	3
	b.	4
	c.	2
	d.	1
Objective 3	a.	2
	b.	3
	c.	1
	d.	4
Objective 4	a.	Locking mechanism
	b.	Power door lock switch
	c.	Power door lock relay
	d.	Actuator
Objective 5	a.	2
	b.	4
	c.	3
	d.	1
Objective 6	a.	Control module
	b.	Signal input device
Objective 7	a.	2
	b.	3
	c.	1
Objective 8	a.	1
	b.	2
	c.	4
	d.	3

Answers to Written Test

Objective 9

a. Speaker lead
b. Harness lead
c. Antenna lead
d. Control unit
e. Amplifier

Objective 10

a. 6
b. 3
c. 2
d. 4
e. 1
f. 5

Objective 11

a. Airbag module
b. Sensing and diagnostic module
c. Clockspring

Objective 12

a. 4
b. 1
c. 3
d. 2
e. 5

Objective 13

a. Follow the manufacturer's procedures for handling, servicing and testing airbag systems and related circuits.

b. Wear safety glasses when servicing an airbag system or handling airbag modules.

c. De-energize the system before servicing live airbag modules. You may also have to de-energize the system when servicing other systems, such as those housed in the steering wheel or steering column.

d. Be careful not to drop, strike or jar sensor modules connected to live airbag systems.

e. Carry live airbag modules with the bag opening (trim cover on driver's airbag module, plastic cover on passenger's module) pointing away from your body.

f. Do not carry airbag modules by the wires or connectors.

g. When (1) placing an airbag module on a bench or other surface, or (2) handling an airbag module attached to a steering column, make sure that the airbag module always faces away from the surface.

h. Follow the disarming procedure exactly. Some systems remain armed for a period of time after power is removed.

Prerequisites:
None

Learning Activities Sheet

Student Name ____________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 and 2.

☐ 4. **Read** Student Supplement 1, "Power Windows".

☐ 5. **Do** Assignment Sheet 1, "Diagnose the Cause of Power Window Problems".

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat steps 3, 4, and 5.

☐ 7. **Do** Job Sheet 1, "Inspect, Test, Repair, and Replace the Parts of a Power Window".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 7.

☐ 9. **Study** Information Sheet, Objective 3.

☐ 10. **Do** Assignment Sheet 2, "Diagnose the Cause of Heated, Lighted, and Electrically Operated Mirror Problems".

☐ 11. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, repeat steps 9 and 10.

Learning Activities Sheet

☐ 12. **Do** Job Sheet 2, "Inspect, Test, Repair, and Replace the Parts of a Heated, Lighted, and Electrically Operated Mirror".

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 12.

☐ 14. **Study** Information Sheet, Objectives 4 through 7.

☐ 15. **Do** Assignment Sheet 3, "Diagnose the Cause of Electric Door Lock Problems".

☐ 16. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, repeat steps 14 and 15.

☐ 17. **Do** Job Sheet 3, "Inspect, Test, Repair, and Replace the Parts of an Electric Door Lock".

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 17.

☐ 19. **Study** Information Sheet, Objective 8.

☐ 20. **Do** Job Sheet 4, "Inspect, Test, Repair, and Replace the Parts of Anti-Theft Systems".

☐ 21. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 20.

☐ 22. **Study** Information Sheet, Objectives 9 and 10.

☐ 23. **Do** Assignment Sheet 4, "Diagnose the Cause of Radio Reception Problems".

☐ 24. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, repeat steps 22 and 23.

☐ 25. **Do** Job Sheet 5, "Inspect, Test, Repair, and Replace the Parts of a Sound System".

☐ 26. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 25.

☐ 27. **Do** Job Sheet 6, "Remove and Reinstall Audio System Components (Unit)".

☐ 28. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 29. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 27.

☐ 29. **Study** Information Sheet, Objectives 11, 12, and 13.

☐ 30. **Do** Assignment Sheet 5, "Diagnose the Cause(s) of the Airbag Warning Light Staying On Or Flashing".

☐ 31. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 32. If the evaluation is not satisfactory, repeat steps 29 and 30.

☐ 32. **Do** Job Sheet 7, "Inspect, Test, Repair, and Replace the Parts of an Airbag System".

☐ 33. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 34. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 32.

☐ 34. **Do** Job Sheet 8, "Inspect, Test, Repair, and Replace the Parts of a Cigar Lighter/Auxiliary Power Outlet".

Learning Activities Sheet

☐ 35. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 36. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 8 and repeat Step 34.

☐ 36. **Do** Job Sheet 9, "Inspect, Test, Repair, and Replace the Parts of a Clock".

☐ 37. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 38. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 9 and repeat Step 36.

☐ 38. **Check** With instructor for any additional assignments to be completed.

☐ 39. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 40. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Teacher Supplement 1—Vehicle Navigation Systems

Introduction

Vehicle "navigation systems" originally served to monitor the speed of the vehicle, the distance traveled, the amount of fuel, and other factors. The system used this information to calculate the estimated times of arrival, the distance that could be traveled on the fuel remaining, the fuel consumption rate (miles or kilometers per gallon), and other useful statistics. Such systems function more as *trip information centers* than as vehicle navigation systems.

More recent systems can assist with *point-to-point navigation*. Four general designs are being pursued:

- **Inertial navigation**—equipment on the vehicle, such as gyroscopes and accelerometers, are used to track movement of the vehicle from a known starting point
- **Radio navigation**—a transmitter/receiver on the vehicle communicates with stations, such as satellites and land-based sites, to track the progress of the vehicle
- **Sign-post navigation**—a receiver on the vehicle picks up a signal from landbased stations to determine the vehicle's position
- **Dead-reckoning**—equipment on the vehicle provides information about the vehicle's changes in direction and the distance traveled to determine the vehicle's location

The inertial navigation system requires expensive equipment to obtain information accurate enough to be useful. The sign-post system would require the installation and maintenance of a nation-wide system of transmitters. Dead-reckoning systems rely on compasses and have not proven to be accurate; they often have errors of one hundred yards or more for every ten miles traveled.

Trip information centers

A *trip information center* uses sensors and an internal clock to perform standard calculations. The specific sensors will vary with the functions performed by the trip information computer. Basic components are the sensors, the computer, the computer controls, and the display. In addition to the sensor, the computer has an internal clock that allows it to measure the passage of time. For example, using the rate of fuel flow and the total remaining fuel, the computer can determine how long the vehicle can travel before running out of fuel. Other standard calculations include:

- fuel economy (miles per gallon) at the present time

- average fuel economy since start of trip (time)
- average speed since start of trip
- distance traveled/distance to go
- time elapsed since start of trip
- estimated time of arrival
- fuel remaining
- distance until fuel tank is empty

The computer display may also show engine parameters, such as rpm or temperature, and other information, such as time of day, outside temperature, direction of travel, etc. Additional sensors may feed the circuit as required to provide the information displayed.

Trip information center controls are generally push buttons. The system is designed so that the number of buttons is kept to a minimum. For example, a single control may allow the driver to step through the functions and the information displayed. Buttons may also be provided to reset the information, clear the display, or change the units of measure. Typically, the display and controls are placed in an overhead console.

Trip information centers normally operate only with the ignition switch in the ON position. Power is provided to memory and time circuits directly from the battery. The components are not serviceable and are generally replaced rather than repaired. You should carefully evaluate customer complaints that the information is incorrect. Some features, such as time, may require *programming* and some, such as compass readings, may require *calibration*. However, most functions that require calculation should be accurate unless the sensors are defective. The customer may simply not understand the information that is being displayed. For example, a customer may not understand that a fuel economy display is for the average economy *since the last reset*, while another display shows fuel economy *over the past few seconds*. Similarly, if the computer is displaying present fuel economy, the driver may not realize that a drop in present fuel economy is expected as the vehicle accelerates to pass a car, causing the driver to think that the display is inaccurate.

GPS navigation systems

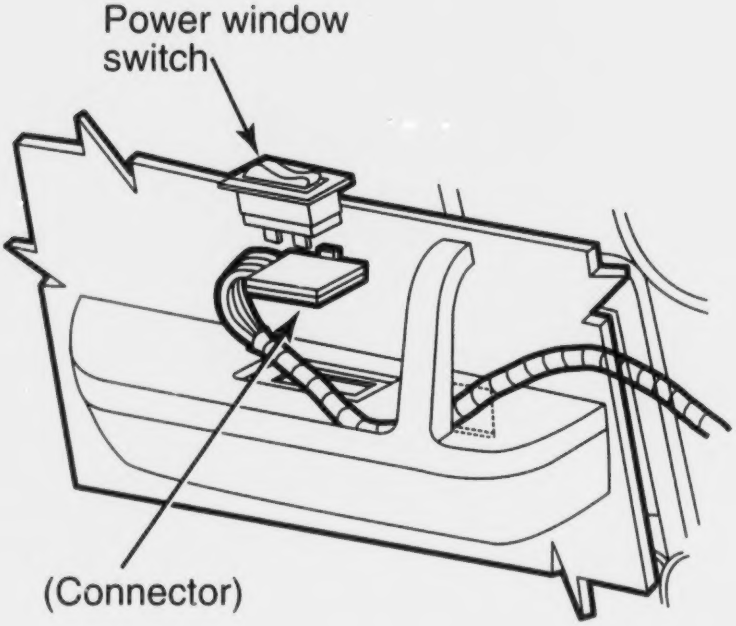
In addition to providing accurate information, the *radio navigation system* has the advantage of using an existing network of satellites to communicate with vehicles. These satellites are called global positioning satellites (GPS). A GPS navigation system works this way:

- vehicles equipped with the system transmit an identification signal to one or more satellites which orbit the earth.
- The satellite analyzes the point of origin of the signal and transmits that information back to the earth, where it is received by the identified vehicle.
- The received satellite signal tells a computer on the vehicle the point of signal origin, and the computer translates that information into map coordinates.
- A screen near the driver shows the vehicle's location on a map or describes the location. Advanced systems can actually plot a route for the driver to follow to reach the desired destination.

The system can also be used to plan *route changes*. The major components of a GPS navigation system are the transmitter/receiver, the computer, and the display and controls. The transmitter/receiver operates automatically whenever the system is on. GPS navigation controls include a power switch and keys or push buttons that allow the driver to select maps, change the size of the map area, input selected commands (such as route changes), and adjust the display. Displays and controls are generally located in a console near the center of the dash. Future systems may use heads-up displays projected onto or embedded in the windshield and may be tied to anticollision systems.

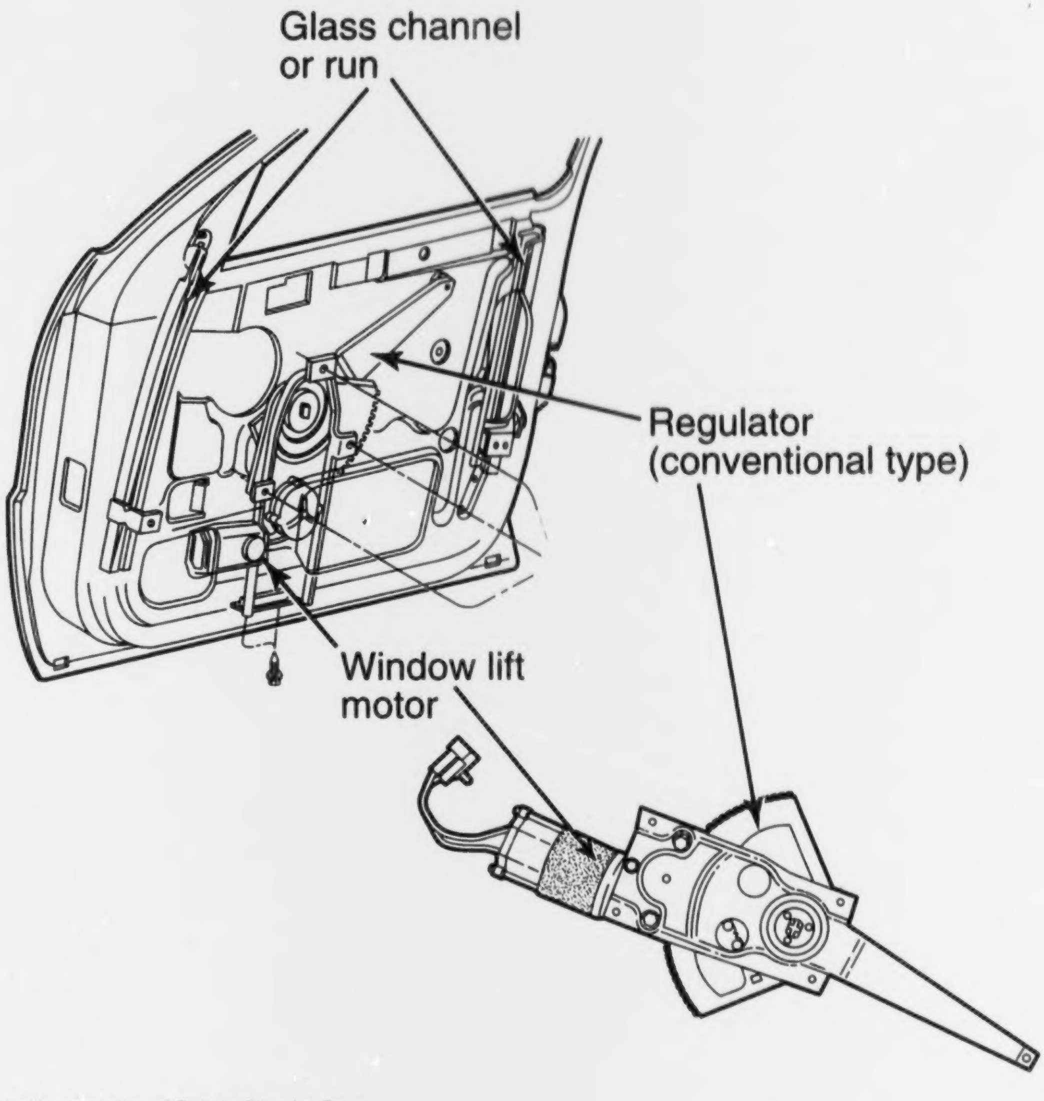
GPS system components are not normally serviceable in the field and must be replaced. However, some systems may require programming or reprogramming by field technicians.

Parts of a Power Window


Power window switch
(Connector)

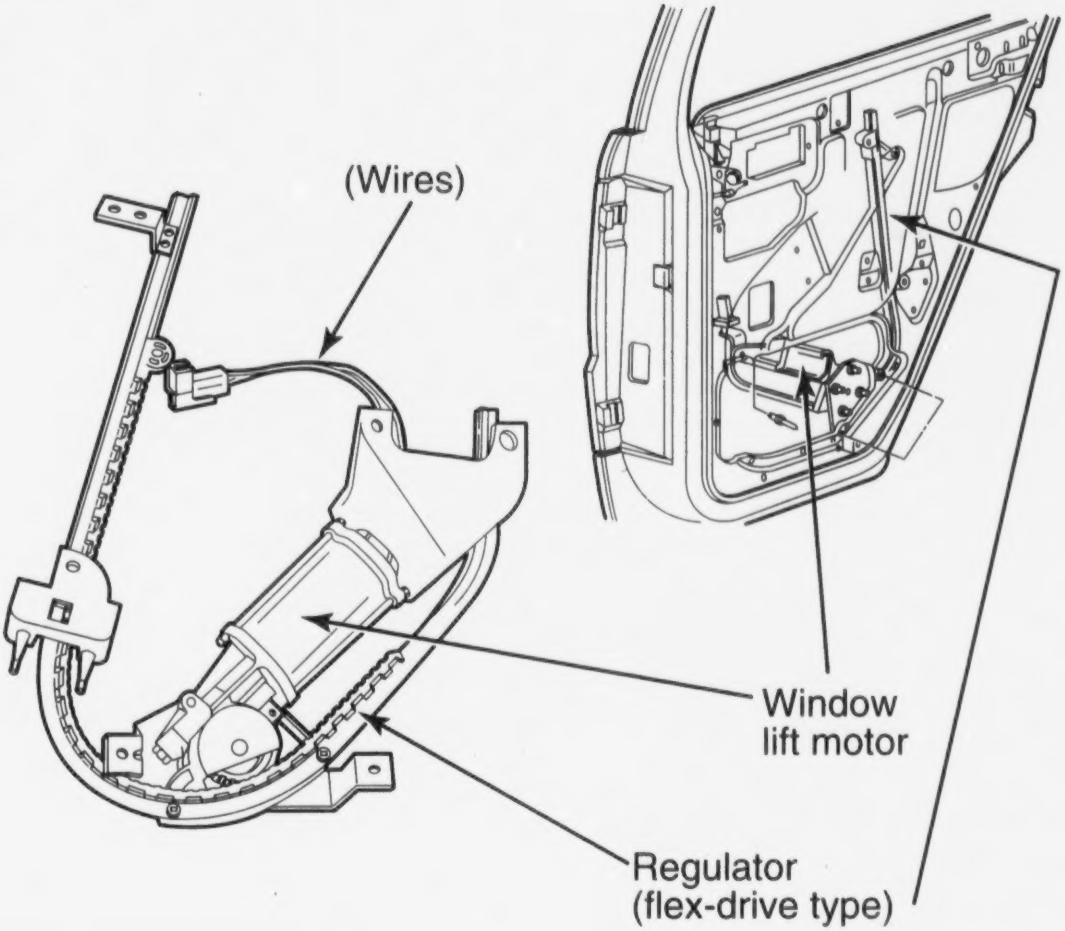
Used with permission of DaimlerChrysler Corp.

Parts of a Power Window
(continued)


Glass channel or run
Regulator (conventional type)
Window lift motor

Used with permission of DaimlerChrysler Corp.

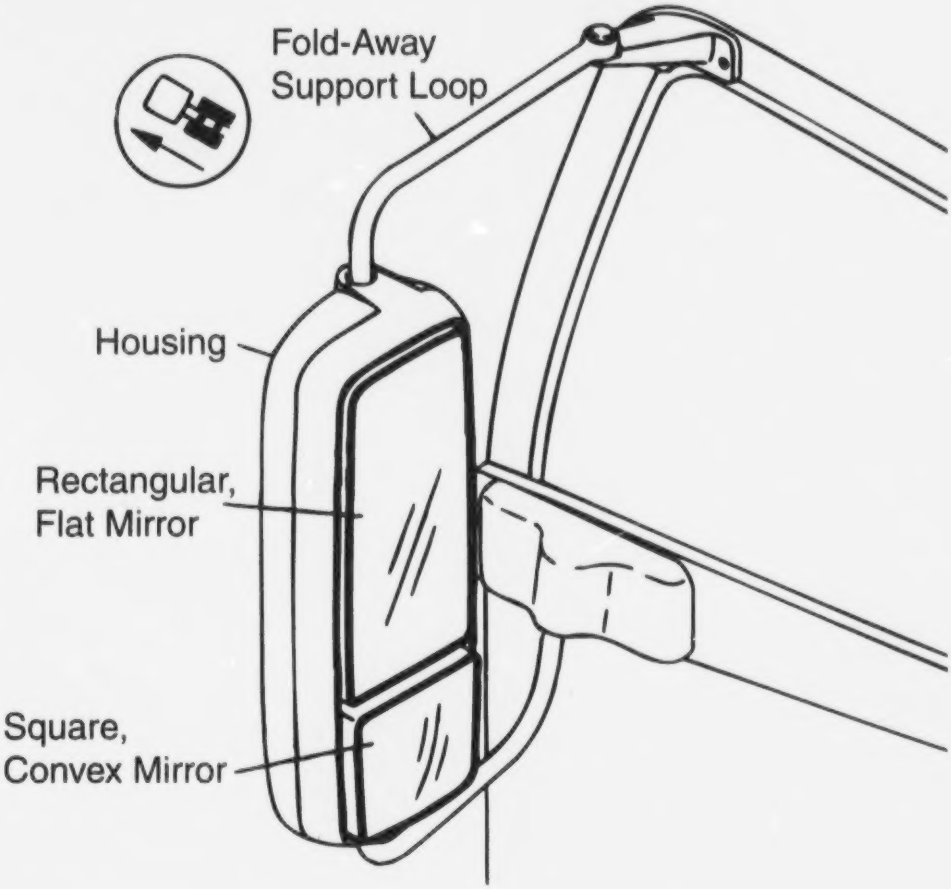
Parts of a Power Window
(continued)



(Wires)
Window lift motor
Regulator (flex-drive type)

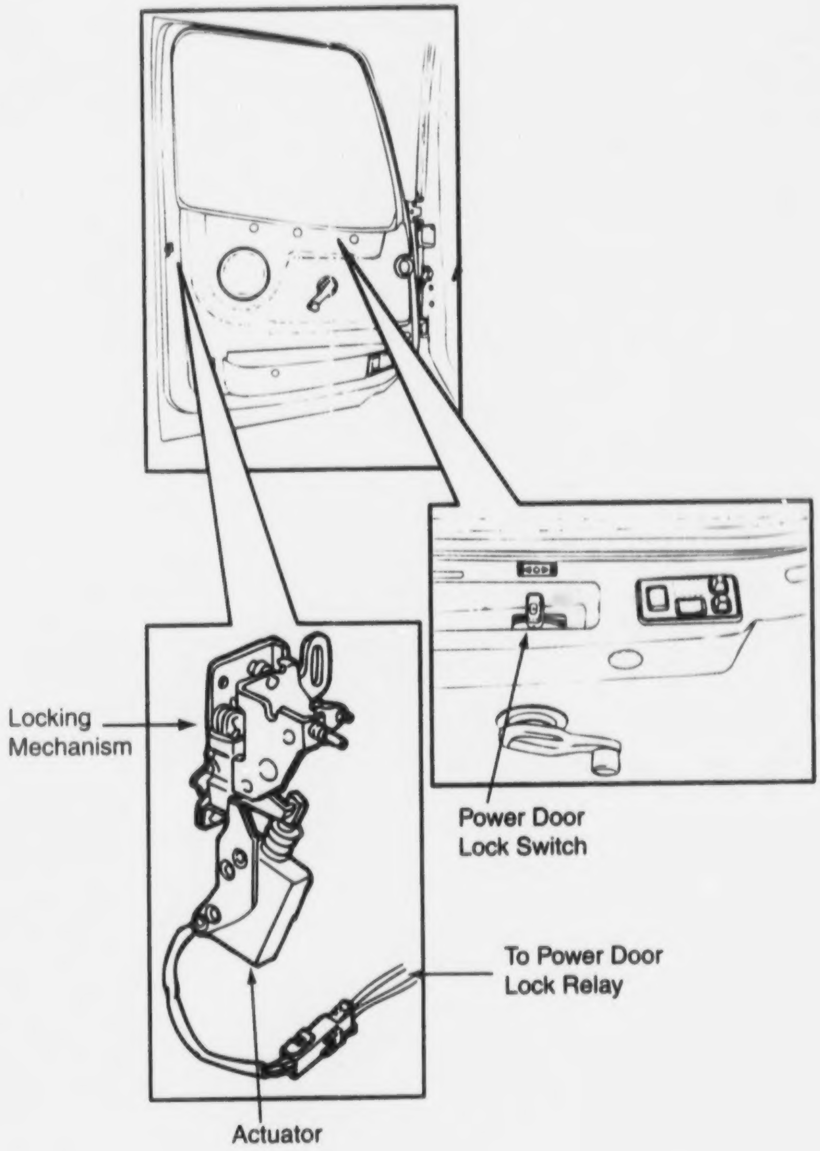
Used with permission of DaimlerChrysler Corp.

Mekra Mirror

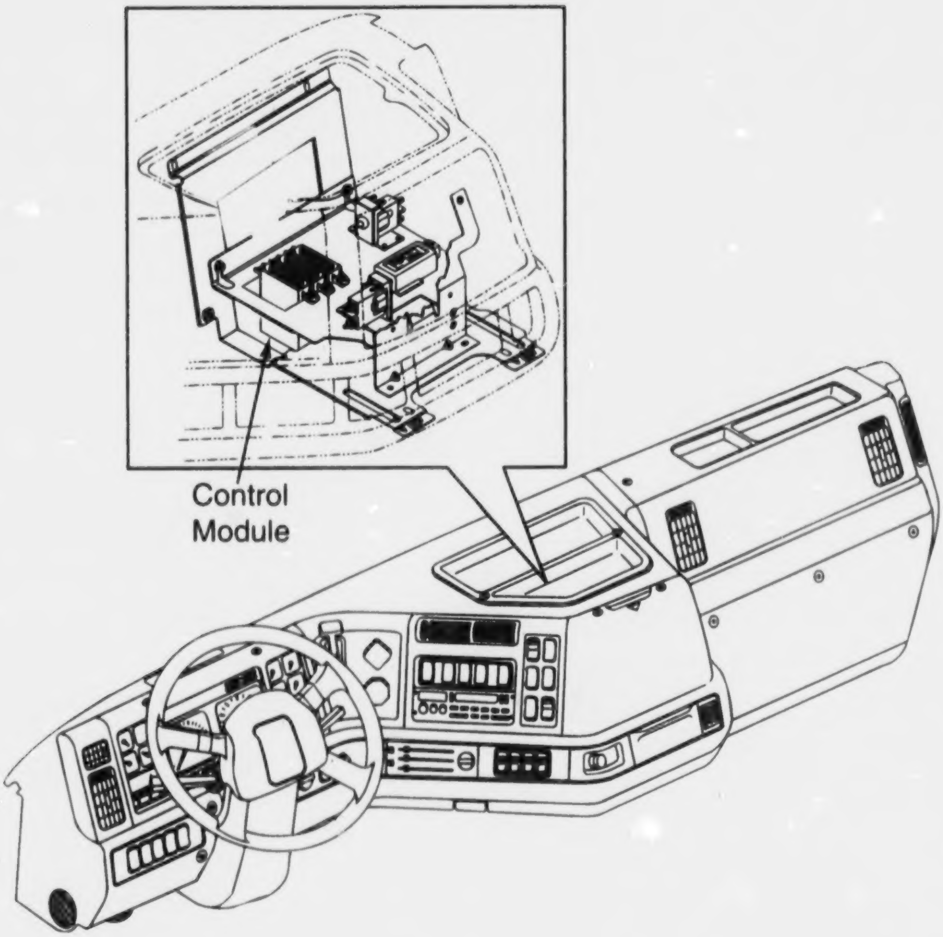

Fold-Away
Support Loop
Housing
Rectangular,
Flat Mirror
Square,
Convex Mirror

Courtesy of Freightliner LLC

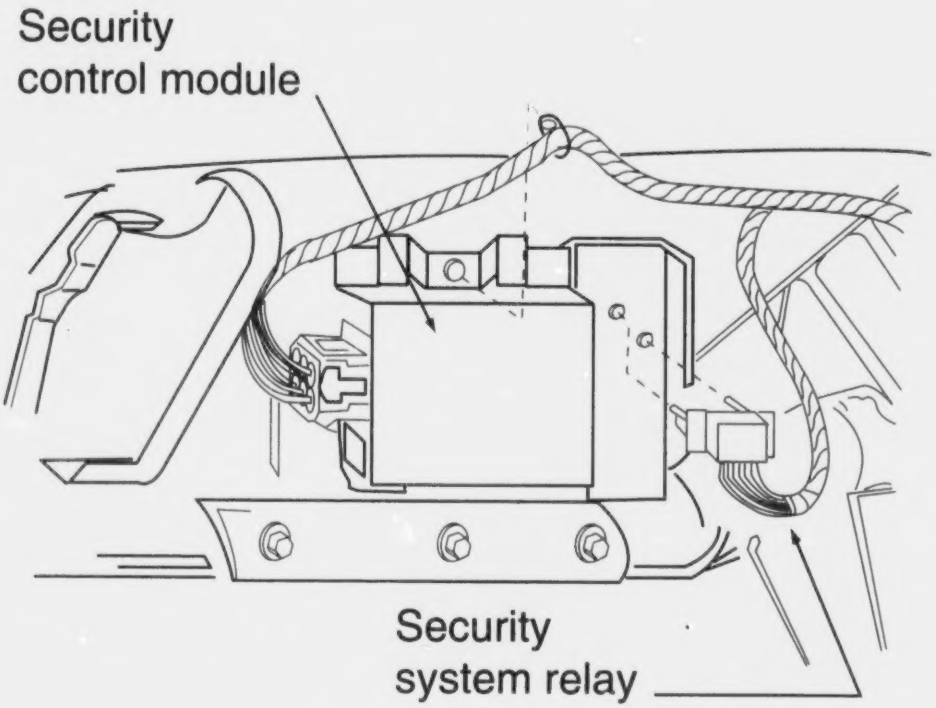
Parts of an Electric Door Lock


Locking Mechanism
Power Door Lock Switch
To Power Door Lock Relay
Actuator

Parts of a Keyless and Remote Lock/Unlock Device

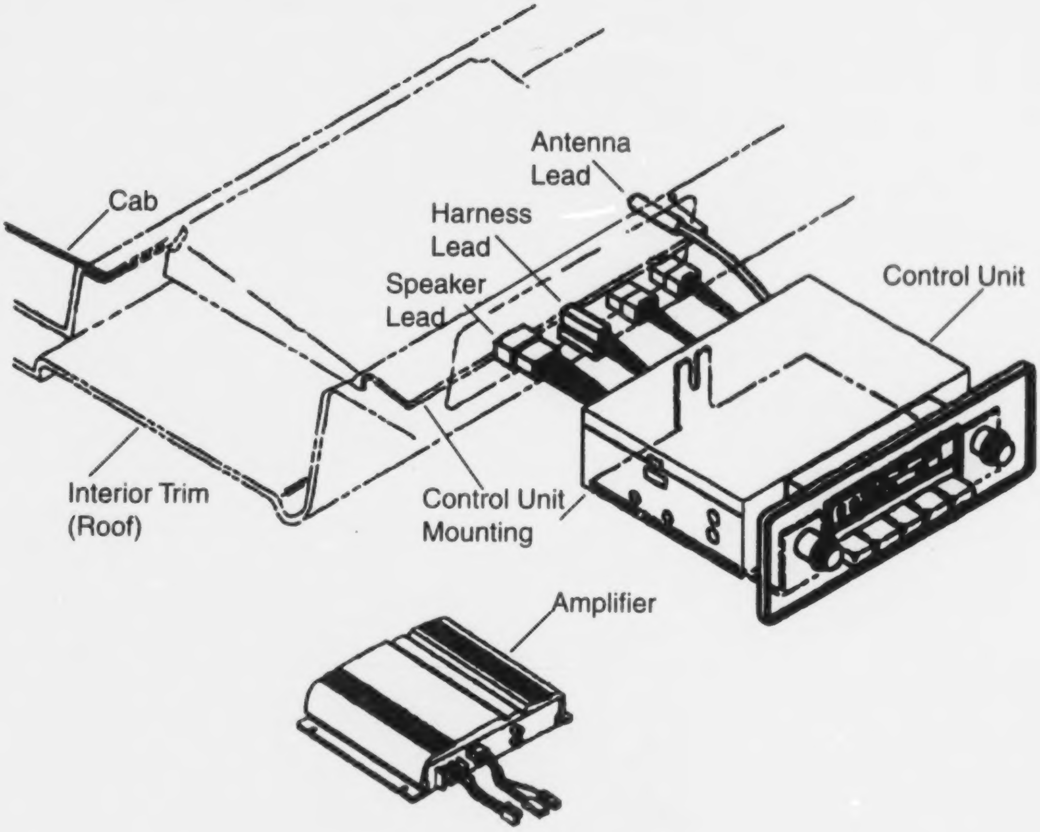

Control
Module

Parts of an Anti-Theft System


Security control module
Security system relay

Copyright © General Motors Corp. Used with permission

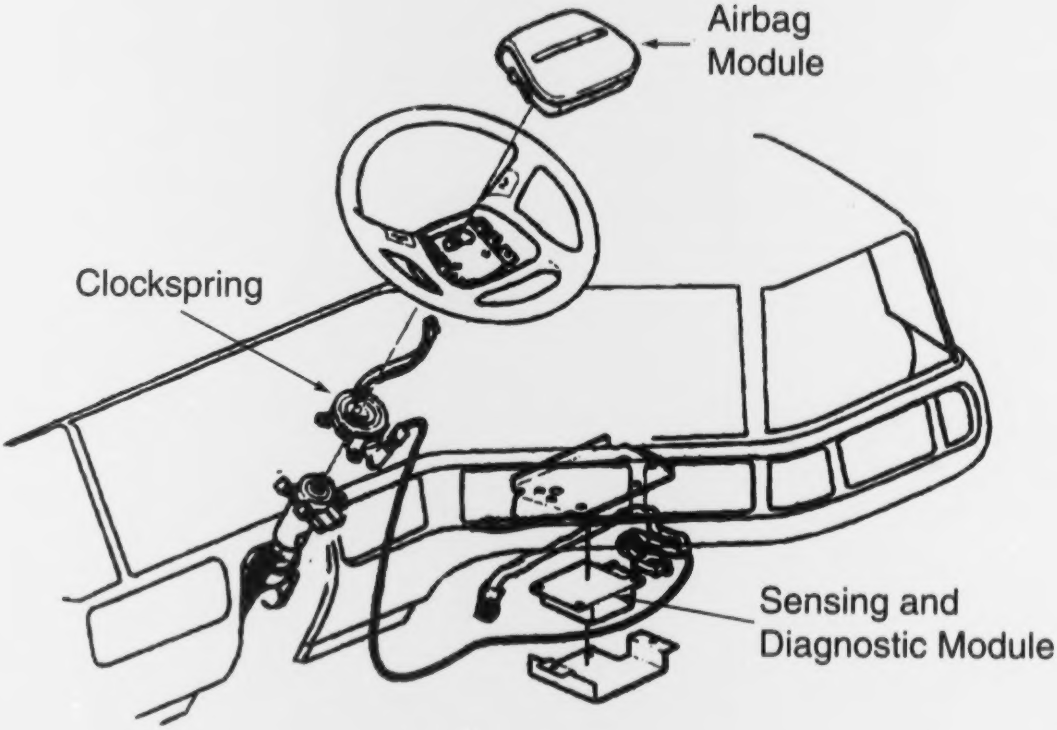
Parts of a Sound System



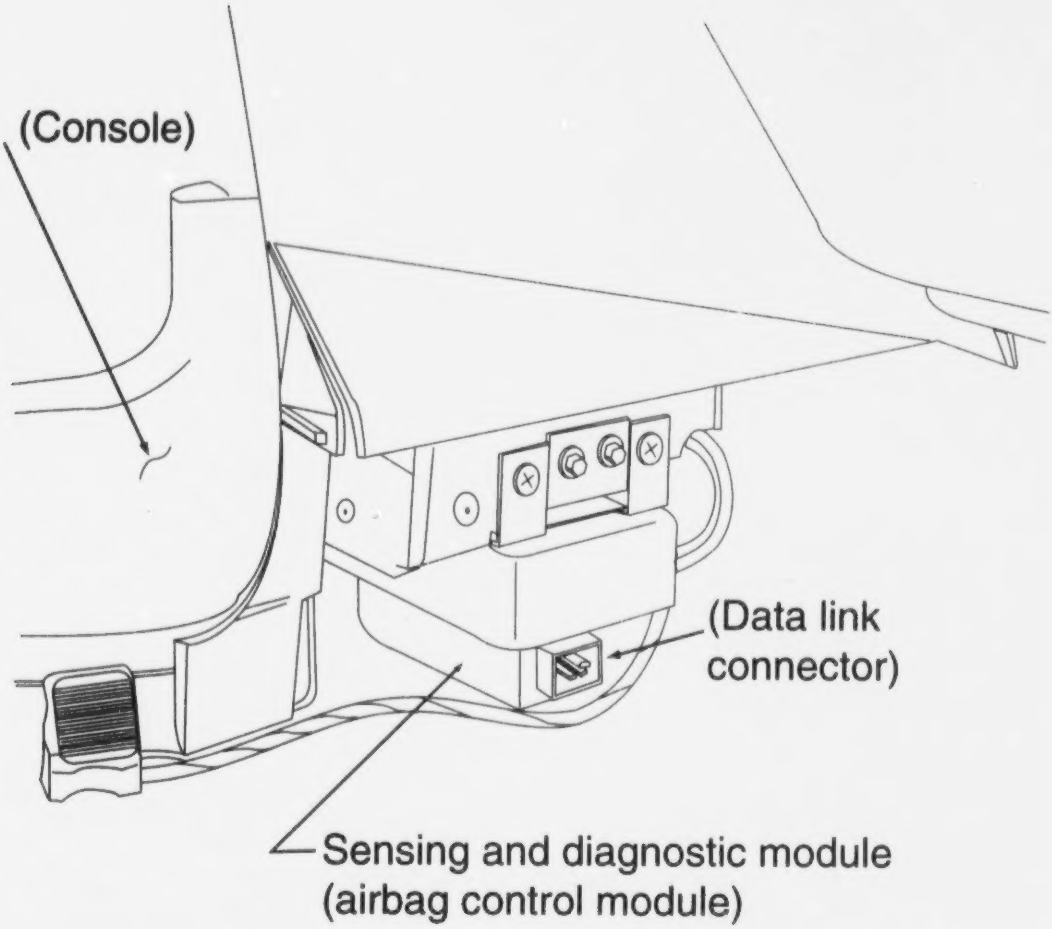
Antenna Lead
Cab
Harness Lead
Speaker Lead
Control Unit
Interior Trim (Roof)
Control Unit Mounting
Amplifier

Courtesy of Freightliner LLC

Parts of an Airbag System

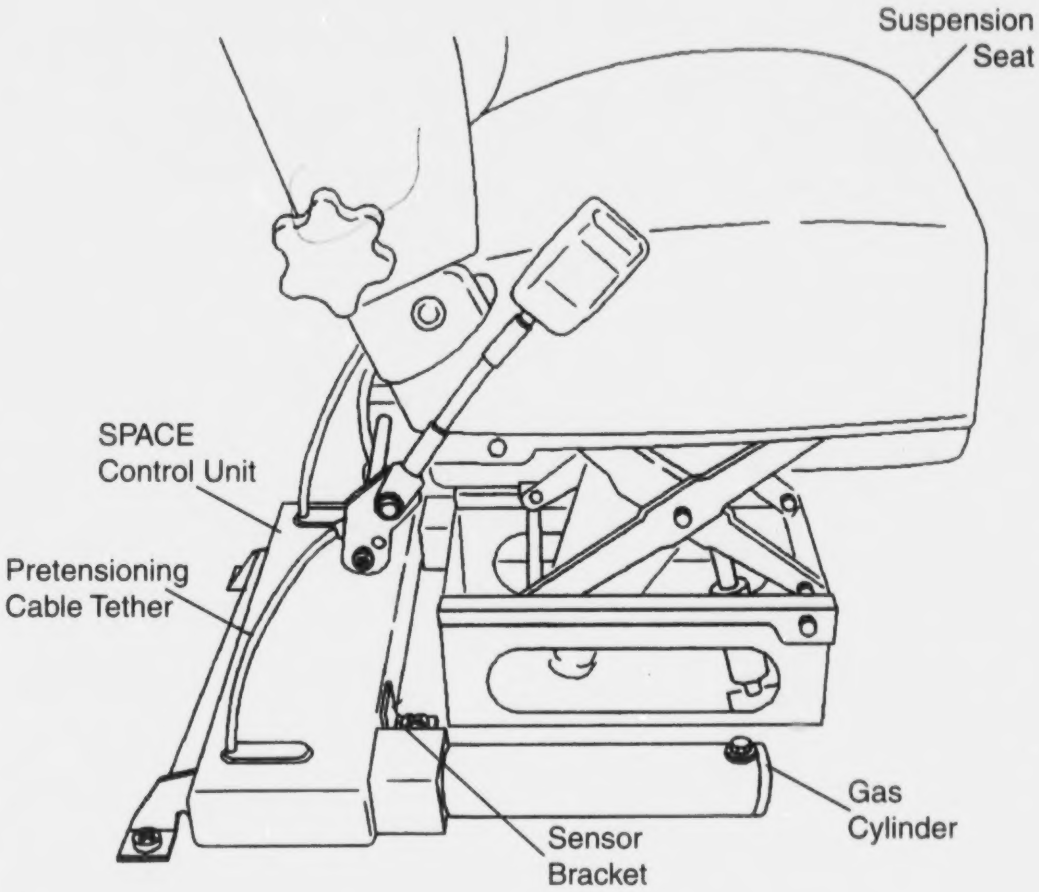

Airbag Module
Clockspring
Sensing and Diagnostic Module

Parts of an Airbag System
(continued)


(Console)
(Data link connector)
Sensing and diagnostic module (airbag control module)

Used with permission of DaimlerChrysler Corp.

Seat Restraint System


Suspension Seat
SPACE Control Unit
Pretensioning Cable Tether
Gas Cylinder
Sensor Bracket

Courtesy of Freightliner LLC

520

Diesel Technology: Electrical and Electronic Systems

Student Edition

Written by

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Developed by

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Unit 7: Charging Systems Diagnosis and Repair
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Unit 1 Introduction to Diesel Electrical and Electronic Systems

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Unit 1

Introduction to Diesel Electrical and Electronic Systems

Objective Sheet

Unit Objective

After completing this unit, the student should be able to state facts about the composition of atoms, magnetism and its relationship to electricity, basic vehicle electrical principles, and complete calculations using Ohm's Law. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to basic electrical principles to their definitions.
2. Identify true statements about atoms.
3. Identify true statements about the electrical charges in atoms.
4. Match terms relating to electron flow to their definitions.
5. State what direction electric current flows in relation to its electromotive force.
6. Distinguish between the conventional and electron theories of current flow.
7. Describe current.
8. Name the two factors that determine the amount of current flowing through a conductor.
9. Match the two types of current to their definitions.
10. Describe voltage.
11. List three sources of voltage for a vehicle's electrical systems.
12. Describe resistance.
13. List five factors that influence resistance as current moves through a circuit.
14. List two results of resistance as current moves through a conductor.
15. State Ohm's law.
16. Write formulas for calculating the current, voltage, and resistance in a conductor.
17. Describe power.
18. List two ways electrical devices can be rated.

Objective Sheet

19. List two common electrical devices that are rated in watts.
20. Match three kinds of magnets to their definitions.
21. Identify true statements about magnets.
22. Match terms relating to magnetism and electromagnets to their definitions.
23. List four properties of electromagnets that make them useful in electrical systems.
24. List three electrical components that use electromagnetism.
25. Calculate current using Ohm's law. (Assignment Sheet 1)
26. Calculate voltage using Ohm's law. (Assignment Sheet 2)
27. Calculate resistance using Ohm's law. (Assignment Sheet 3)
28. Predict changes in voltage, current, and resistance in a circuit. (Assignment Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **Atom**—The smallest unit of an element that still has all the characteristics of that element

b. **Circuit**—A series of electrically or electromagnetically connected components or devices capable of conducting electric current

c. **Compound**—A substance made up of two or more elements that are joined by chemical forces

d. **Conductor**—A substance that transmits an electric charge

Examples: copper, aluminum

e. **Element**—A form of matter that cannot be reduced to a simpler substance by normal chemical means

f. **Insulator**—A substance that prevents the passage of an electric charge

Examples: plastic, rubber, glass, ceramic

g. **Matter**—Anything that occupies space and can be perceived by one or more of our senses

h. **Molecule**—The smallest particle into which a compound can be divided without changing its chemical and physical properties

i. **Semiconductor**—A substance that neither transmits an electric charge well nor prohibits the passage of an electric charge well

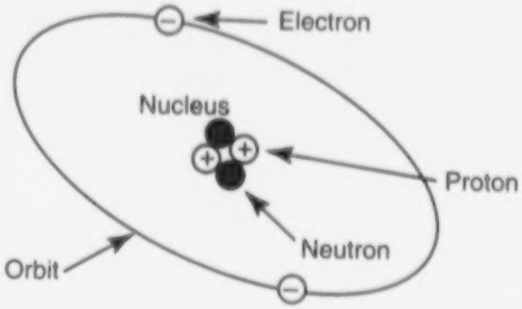
Examples: silicon, geranium

j. **Voltage drop**—The voltage lost or consumed as current moves through resistance

Objective 2

Composition of atoms

Figure 1



a. Three particles make up an atom (Figure 1). They are:

- proton
- neutron
- electron

b. The central core of an atom is called the nucleus.

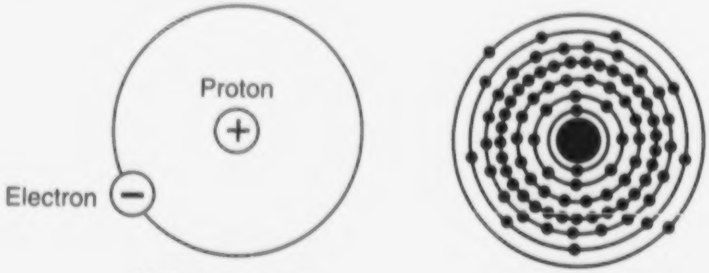
c. Protons and neutrons are located in the nucleus.

d. Electrons rotate around the nucleus in fixed orbits (or shells).

e. Each orbit (shell) can only hold a limited number of electrons.

f. The number of orbits (shells) an atom has depends on how many electrons it has. (Figure 2)

Figure 2



Hydrogen atom (Number of electrons = 1)

Uranium atom (Number of electrons = 92)

g. The outermost orbit of electrons of any atom is called the valence orbit (shell).

h. All the atoms of an element have the same number of protons.

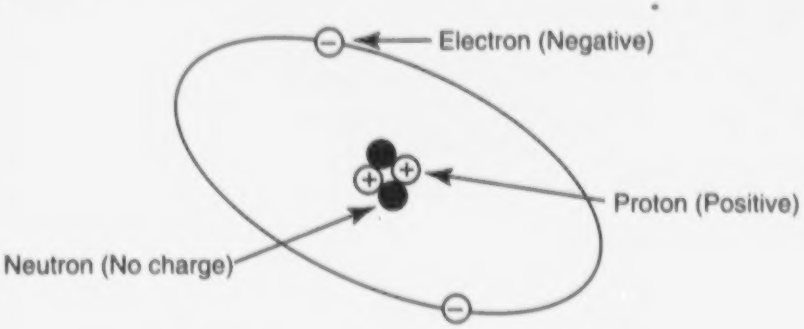
i. An element's atomic number is equal to the number of protons in its nucleus.

j. Every element has a different atomic number.

Objective 3

Electrical charges in atoms

Figure 3



a. Atomic particles have electrical charges (Figure 3):

- proton — + (positive charge)
- electron — - (negative charge)
- neutron — (no charge)

b. Unlike electrical charges attract each other.

c. Like electrical charges repel each other.

d. Electrons are held in orbit around the nucleus by the strong attraction between the negatively (-) charged electrons and the positively (+) charged protons.

e. Electrons remain evenly spaced in the orbits (shells) because their like charges repel each other.

f. Neutrons do not have an electrical charge, but have the ability to cancel the repelling force between the protons, thus holding the nucleus together.

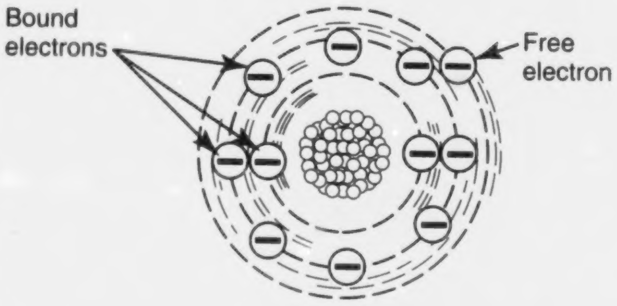
g. An atom is held together by a balance of electrical charges within it.

Information Sheet

Objective 4

Terms relating to electron flow and their definitions

Figure 4



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a. **Bound electrons**—Electrons in an atom's inner orbits (shells) (Figure 4)

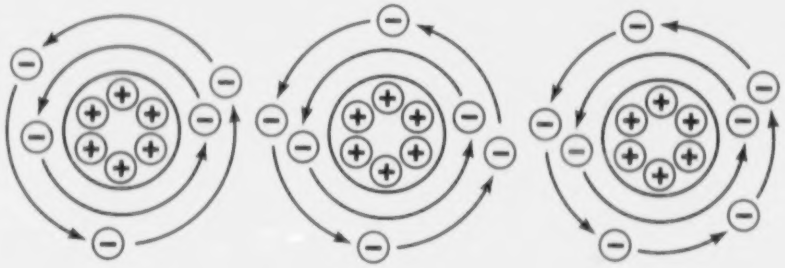
b. **Free electrons**—Electrons in an atom's valence orbit (shell) (Figure 4)

c. **Electron drift**—Electrons moving from one atom to another

d. **Electromotive force**—A force which causes electrons to move out of their orbit

Note: An electromotive force is the source of the electrical charge that creates electric current.

Figure 5



Unbalanced
(Positive ion)
(6 protons, 5 electrons)

Balanced
(6 electrons, 6 protons)

Unbalanced
(Negative ion)
(6 protons, 7 electrons)

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e. **Balanced atom**—An atom which has the same number of protons as it has electrons (Figure 5)

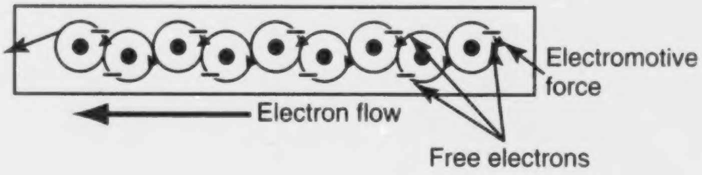
f. **Unbalanced atom**—An atom which has a different number of protons than it has electrons (Figure 5)

Note: An atom that has more protons (+) than electrons (–) is called a positive ion; an atom that has more electrons than protons is called a negative ion.

Objective 5

Direction that current flows in relation to its electromotive force

Figure 6



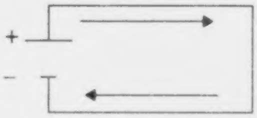
Current moves *away* from its electromotive force. (Figure 6)

Objective 6

Two theories on current flow

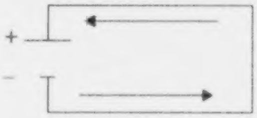
a. The *Conventional Theory* states that current flows from the positive terminal, through conductors, back to the negative terminal.

Figure 7



b. The *Electron Theory* states that current flows from the negative terminal, through conductors, back to the positive terminal.

Figure 8



Note: Current flow is a controversial topic. Either theory can be used, but the trucking industry uses the conventional theory. Therefore, the conventional theory is used throughout this publication.

Information Sheet

Objective 7

Description of current

Figure 9

CURRENT	
Definition:	**Current** is a flow of electric charge moving through a conductor.
Unit of Measurement:	**ampere** or **amp** **NOTE:** An ampere measures current in terms of the number of electrons that pass a given point in a conductor within one second. One ampere equals the movement of 625 billion billion electrons.
Abbreviation:	**A**
Symbol:	**I** (intensity of electron flow)
Measurement Instrument:	**ammeter** or **multimeter**

Objective 8

Two factors that determine the amount of current flowing through a conductor

a. Voltage

b. Resistance

Note: If voltage or resistance is changed, current flow will also change.

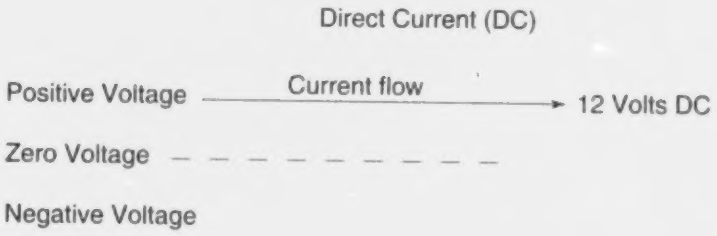
Objective 9

Two types of current and their voltage sources

a. Direct current (DC)—Flows in only one direction

Source: battery

Figure 10—Graph of DC Current

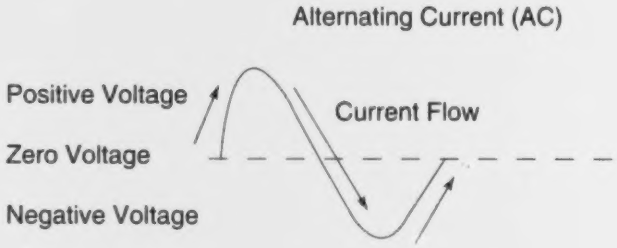


Note: Direct current (DC) is most commonly used in a heavy vehicle.

b. Alternating current (AC)—Flows first in one direction, then in the other direction.

Sources: alternator, generator

Figure 11—Graph of AC Current


Alternating Current (AC)
Positive Voltage
Current Flow
Zero Voltage
Negative Voltage

Objective 10

Description of voltage

Figure 12

VOLTAGE	
Definition:	**Voltage** is the difference in electrical potential between two points in a circuit. **NOTE:** Voltage is sometimes referred to as electromotive force (EMF), potential, or electrical pressure.
Unit of Measurement:	**volt**
Abbreviation:	**V**
Symbol:	**E** (**e**lectromotive force = voltage)
Measurement Instrument:	**voltmeter** or **multimeter**

Objective 11

Two sources of voltage in vehicle electrical systems

a. Battery

b. Alternator/Generator

Objective 12

Description of resistance

Figure 13

RESISTANCE	
Definition:	**Resistance** is opposition to the flow of current in a conductor.
Unit of Measurement:	**ohm**
Abbreviation:	Ω **NOTE:** The Greek letter, Omega, is used for the abbreviation of *ohm*.
Symbol:	**R**
Measurement Instrument:	**ohmmeter** or **multimeter**

Objective 13

Five factors that influence resistance as current moves through a circuit

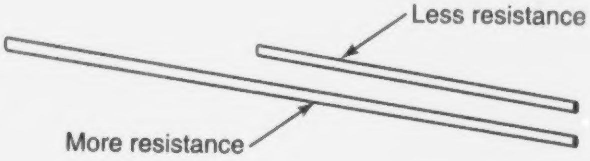
a. Type of material conducting the current

Note: Some materials (such as copper, gold, and aluminum) have less resistance than others

b. Length of the conductor

Note: Current encounters more resistance the greater distance it must travel through a conductor. (Figure 14)

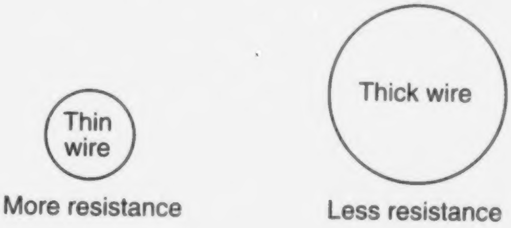
Figure 14



c. Diameter of the conductor

Note: Thick wire has less resistance than thin wire. (Figure 15)

Figure 15



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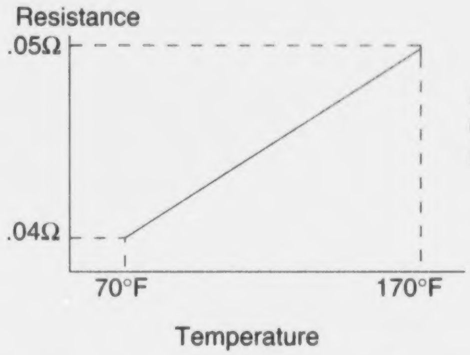
d. Temperature of the conductor

Figure 16



A hotter wire creates more resistance

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Note: Resistance is usually lower in materials that are cooler.

e. Physical condition of the conductor

Note: A cut, nicked, kinked, or corroded conductor has a higher resistance to current.

Objective 14

Two results of resistance as current moves through a conductor

a. Voltage always drops after encountering resistance.

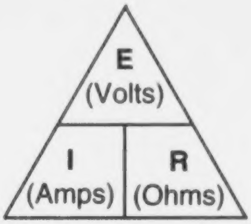
b. Some of the electrical energy changes to another form of energy such as heat, light, or motion after encountering resistance.

Objective 15

Ohm's law—It takes one volt of electrical pressure to push one ampere of electrical current through one ohm of electrical resistance.

Mathematical formula

$$I = \frac{E}{R}$$



- E = voltage (EMF, electromotive force, or electrical pressure)
- I = current (intensity of electron flow)
- R = resistance

Note: As an aid to remembering Ohm's Law and where each letter falls in the triangle, try to memorize the expression: "**E**ven **I** **R**emember".

Information Sheet

Objective 16

Formulas for calculating current, voltage, and resistance in a conductor

a. Current

$$I = \frac{E}{R}$$

Note: Amps = $\frac{\text{Volts}}{\text{Ohms}}$ The number of amps equals the number of volts divided by the number of ohms.

b. Voltage

$$E = I \times R$$

Note: Volts = Amps x Ohms The number of volts equals the number of amps multiplied times the number of ohms.

c. Resistance

$$R = \frac{E}{I}$$

Note: Ohms = $\frac{\text{Volts}}{\text{Amps}}$ The number of ohms equals the number of volts divided by the number of amps.

Objective 17

Description of power

Figure 17

POWER	
Definition:	**Power** is the rate at which work is done.
Unit of Measurement:	**watt** **NOTE:** One watt is equal to 1 amp multiplied times 1volt.
Abbreviation:	**W**

Objective 18

Two ways electrical devices can be rated

a. Ohms of resistance

b. Watts of power capacity

Objective 19

Two common electrical devices that are rated in watts

a. Resistors

b. Small lamps

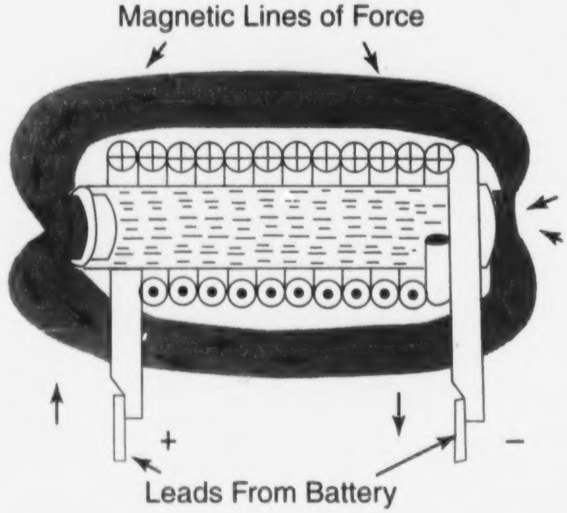
Note: All lights and light bulbs on a vehicle are called lamps.

Objective 20

Three kinds of magnets and their definitions

a. **Electromagnet**—A man-made magnet that only has magnetic qualities when influenced by an electric field (Figure 18)

Figure 18



Note: Electromagnets are created by inserting a soft iron core inside a coil of wire and conducting electricity through the wire. The iron core has magnetic qualities when current flows through the surrounding coil; however, when the current is turned off, the iron core loses its magnetic qualities.

b. **Natural magnet**—a magnetic material that occurs naturally

Examples: The minerals magnetite and lodestone

c. **Permanent magnet**—a man-made magnet that keeps its magnetic qualities indefinitely

Note: Permanent magnets are made by placing an object made of an iron or steel alloy into an intense magnetic field.

Objective 21

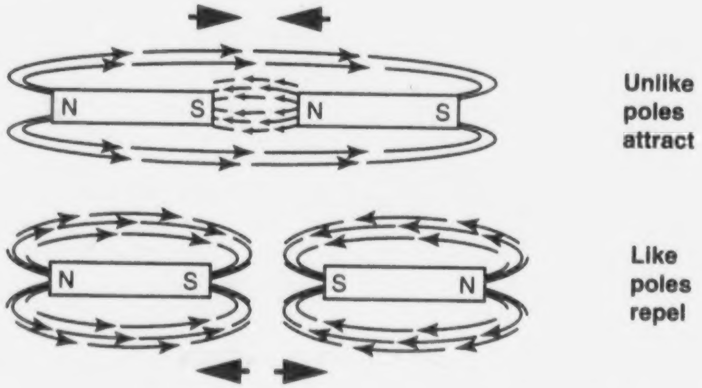
Facts about magnets

a. Magnetic force is invisible.

b. All magnets have poles, usually called the north pole and the south pole. (Figure 19)

c. Like poles repel; unlike poles attract. (Figure 19)

Figure 19


N
S
N
S
Unlike poles attract
N
S
S
N
Like poles repel

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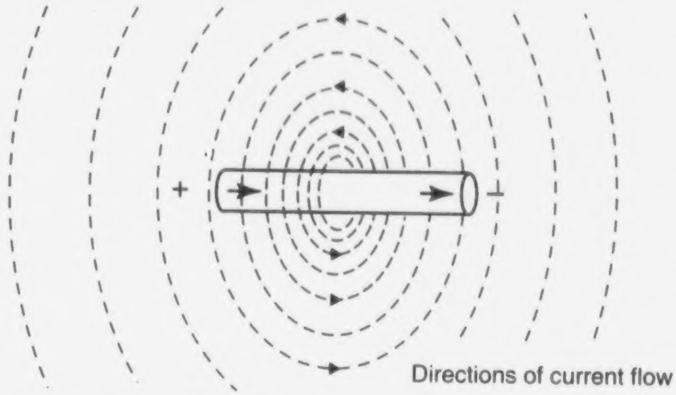
d. Some materials magnetize easily; other materials do not magnetize at all.

e. A magnetic field cannot be insulated.

f. All conductors carrying electricity create a magnetic field. (Figure 20)

Figure 20


+
–
Directions of current flow

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g. Magnetism can be used to produce electricity.

h. Electricity can be used to produce magnetism.

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Objective 22

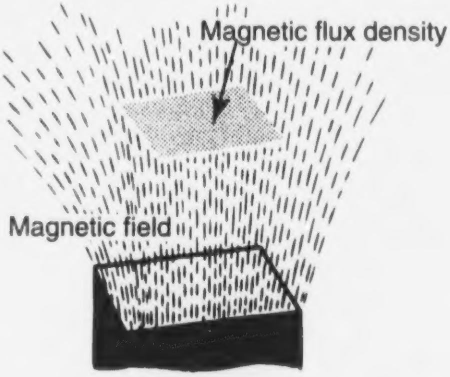
Terms relating to magnetism and electromagnets and their definitions

a. **Magnet**—an object that is surrounded by a magnetic field and has the capacity to attract certain materials

b. **Magnetism**—the force exerted by magnets

c. **Magnetic field**—the space around a magnet where the force of the magnet can be detected (Figure 21)

Figure 21



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d. **Flux lines**—imaginary lines that define a magnetic field

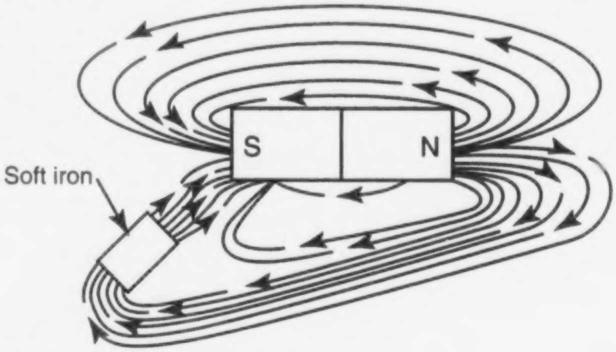
e. **Flux density**—the number of flux lines per inch (Figure 21)

f. **Magnetic flux**—the strength of the magnetic force operating in a magnetic field

g. **Magnetic permeability**—how easily magnetic forces pass through a substance

h. **Magnetic reluctance**—how difficult it is for magnetic forces to pass through a substance (Figure 22)

Figure 22



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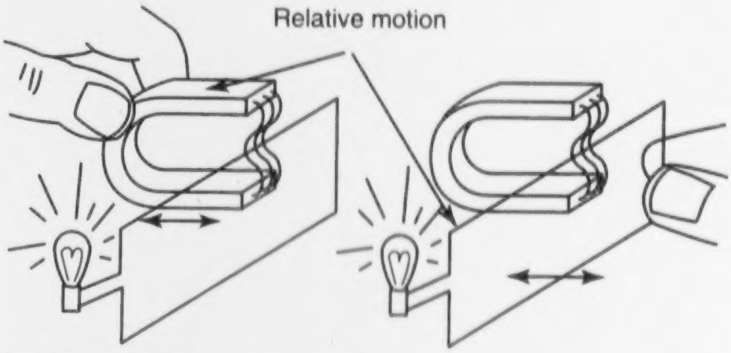
i. **Electromagnetic induction**—The process of creating voltage using magnets (Figure 23)

Figure 23



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Objective 23

Four properties of electromagnets that make them useful in a vehicle's electrical system

a. They can be turned on and off.

b. They can achieve a very high level of magnetic force.

c. The strength of their magnetic force can be adjusted.

d. They can be used to increase, decrease, and control voltage.

Objective 24

Three vehicle electrical components that use electromagnetism

a. Electric motors

b. Solenoids

c. Relays

Note: Almost any electrical device or component that changes electrical energy into movement uses electromagnetism.

Student Supplement 1—Matter and Atoms

Matter

Everything in the world is made up of matter—anything that occupies space and can be perceived by one or more of our senses. There are three forms of matter—solids, liquids, and gases. The building blocks of matter are called elements. An element is a form of matter that cannot be reduced to a simpler substance by normal chemical means. In nature there are over a hundred known elements. Some elements are familiar—hydrogen, oxygen, gold, sodium, and copper, and some are not so familiar—antimony, lithium, gallium, and germanium.

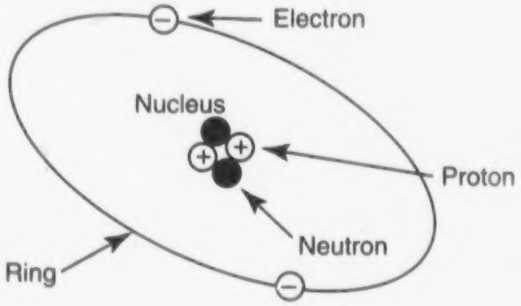
A compound is a substance made up of two or more elements that are joined by chemical forces. The individual atoms of the elements in a compound are actually constructed into a new—and very precise—arrangement called a molecule. A molecule is the smallest particle into which a compound can be divided without changing its chemical and physical properties. Just as atoms are the smallest possible unit of an element, molecules are the smallest possible unit of compounds.

Atoms

An atom is the smallest unit of an element that still has all the characteristics of that element. An atom is so small that it cannot even be seen with an ordinary microscope; it would take billions of atoms to form the head of a pin. Small as they are, every atom consists of even smaller particles—protons, neutrons, and electrons.

In an atom, the protons and neutrons are located together in the atom's nucleus, or central core (Figure 1). The electrons rotate around the nucleus in fixed orbits (or shells) in much the same way as planets orbit the sun. Each atom has an equal number of protons and electrons. If, for example, the atom has 8 protons (the element oxygen), it also has 8 electrons.

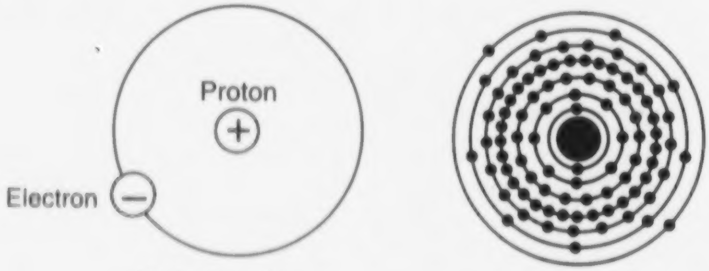
Figure 1



The number of protons in an atom's nucleus is different for different elements. For example, atoms of the element hydrogen each have 1 proton, helium atoms have 2 protons, lithium has 3 protons, beryllium has 4, and so on. This number—the number of protons in an atom's nucleus—is referred to as the element's atomic number and is different for every element.

Note: It is possible, but not usual, for atoms of the same element to have different numbers of neutrons in their nucleus. Atoms in which this occurs are called isotopes, and although such atoms have the same chemical properties as regular atoms of the element, they may have slightly different physical properties.

Figure 2



Hydrogen atom
(Number of
electrons = 1)

Uranium atom
(Number of
electrons = 92)

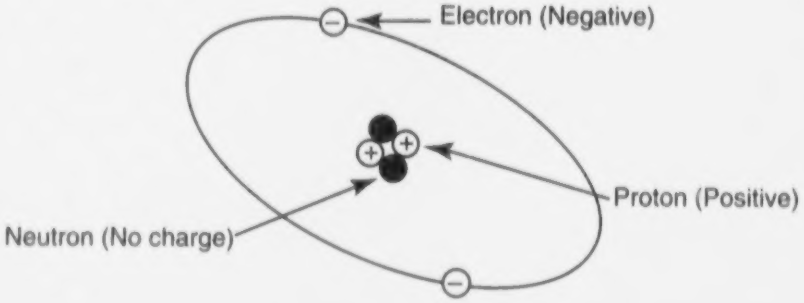
The number of orbits (or shells) an atom has depends on how many electrons the atom has. Each orbit can hold only a limited number of electrons. The orbit nearest the nucleus can only hold 2 electrons, the second orbit can hold 8, the third orbit can hold 18, and so on. A simple atom like hydrogen has one electron in its one orbit. A more complex atom like uranium has ninety-two electrons in seven orbits (Figure 2). An atom's outermost orbit of electrons is called the valence orbit (shell). In the illustration you can see that hydrogen has one electron in its valence orbit and uranium has two electrons in its valence orbit.

Student Supplement 2—How Electricity is Created

Electrical Charges in Atoms

The particles that make up atoms are electrically charged (Figure 1). Protons have a positive (+) charge, electrons have a negative (-) charge, and neutrons have no charge (Figure 1). Atoms are held together by the balance of these electrical charges.

Figure 1



The electrical charges of the particles also help explain the structure of the atom and how an atom behaves. To explain how this works, you must know some facts about electrical charges:

- *Unlike electrical charges attract each other.*
- *Like electrical charges repel one another.*

Although neutrons do not have an electrical charge, they do have the ability to cancel the repelling force between the like charges of protons, holding the nucleus together. The electrons are held in orbit by their attraction to the protons. Because of their unlike charges, the electrons are repelled by one another and don't get too close to each other as they orbit. This explains why the number of electrons in each orbit is limited. If the electrons get too crowded in an orbit, they "repel" any additional electrons into a new orbit a little farther out from the nucleus.

Electron Flow

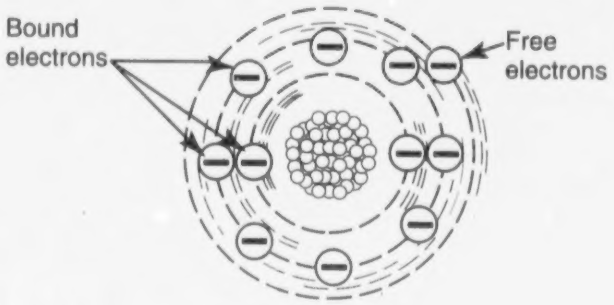
Because the number of electrons (-) in an atom is equal to the number of protons (+), the electrical charges cancel each other, leaving the atom itself with no electrical charge. The atom is said to be a balanced atom—it has the same number of electrons that it has protons. It is the number of electrons in an element's valence (outermost) orbit that can cause an atom to become unbalanced; here's how—

Because the electrons in an atom's inner orbits are closer to the protons than are the electrons in an atom's valence orbit, these innermost atoms are attracted more strongly by the positive charge of the atom's nucleus.

Example: Think of a magnet. When a metal object gets close enough to a magnet, the magnet pulls the object to it. The closer the object gets to the magnet, the stronger the magnetic pull.

The electrons in an atom's inner orbits are called bound electrons; the electrons in an atom's valence orbit are called free electrons (Figure 2). The use of these terms describes the strength of the hold the nucleus has on electrons located in these different positions.

Figure 2



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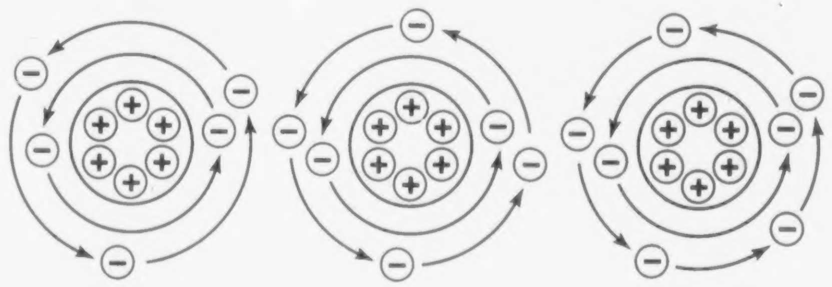
Sometimes an electromotive (electron-moving) force, created by heat, light, pressure, chemical action, or magnetism, can cause a free electron in an atom to move out of its valence orbit.

Figure 3



Unbalanced (Positive ion)

Balanced (6 electrons, 6 protons)

Unbalanced (Negative ion)

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When an electron moves out of its orbit, it immediately becomes attracted by a nearby atom's nucleus, and the electron attaches itself to the new atom. Both atoms—the one that lost the electron and the one that gained the electron—are now unbalanced atoms; they both have a different number of protons than they have electrons. (Figure 3)

- The atom that just lost the electron now has a positive (+) charge—it has one more proton (+) than it has electrons (-).

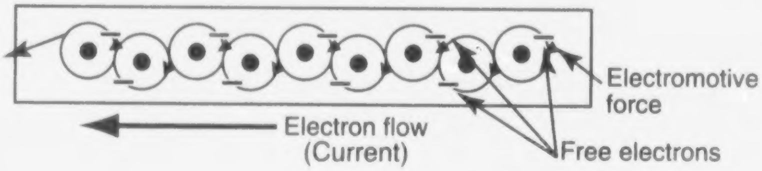
  Note: An unbalanced atom that has more protons (+) than electrons (-) is called a positive ion.

- The atom that just gained the electron now has a negative (-) charge—it has one more electron (-) than it has protons (+).

  Note: An unbalanced atom that has more electrons (-) than protons (+) is called a negative ion.

When one atom has a positive charge and another atom has a negative charge, things begin to happen very rapidly. Both atoms seek to balance their charge. The atom with the positive charge quickly attracts negatively charged free electrons. The atom with the negative charge immediately wants to get rid of its extra electron. A chain reaction starts where all the nearby atoms instantly begin gaining and losing electrons from each other. (Remember: the electromotive force is still operating, encouraging such electron movement.)

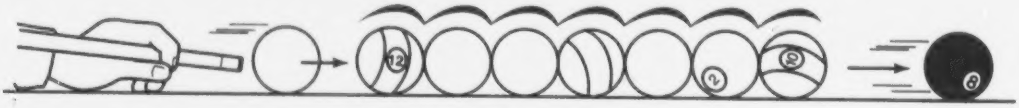
Figure 4



When electrons move from one atom to another in this way it is called electron drift. If an electromotive force is present, the moving electrons will always move in one direction—away from the electromotive force. Such organized movement of electric charge in one direction is called electric current and supports the conventional theory of current flow (see Objective 6).

Electric current as it moves through a conductor (such as a wire) is sometimes described as being like water moving through a pipe. Although this description is useful in imagining electric current, actually a more accurate description would be to imagine a line of balls on a pool table where each ball touches the balls on either side of it (Figure 5). When the player strikes the first ball in line with the cue, the energy of the strike is transmitted to every ball in turn. Unlike water flowing through a pipe, free electrons from the battery do not actually pour into the wire, moving through it until they all emerge out the other end. It is the electrical charge (energy) that is transmitted, not physical matter.

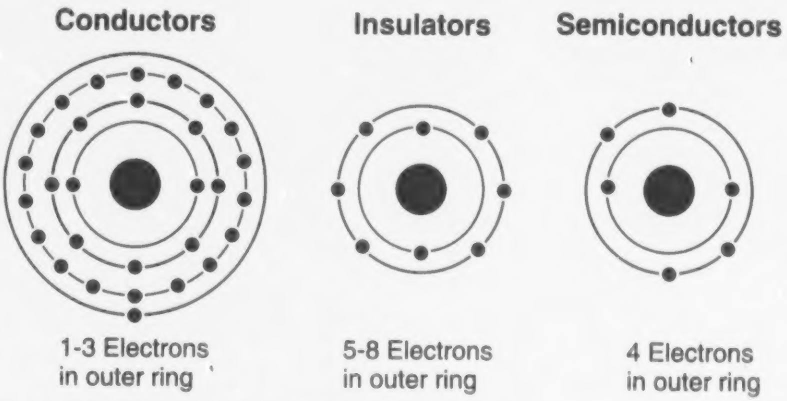
Figure 5



Conductors, Insulators, and Semiconductors

Some substances conduct electricity more easily than others. How good a conductor an element is depends on the number of electrons in its valence orbit. The fuller an atom's valence orbit is to its maximum number of electrons, the stronger the atom holds the electrons (Figure 6).

Figure 6


Conductors
Insulators
Semiconductors
1-3 Electrons in outer ring
5-8 Electrons in outer ring
4 Electrons in outer ring

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Conductors—Substances that transmit an electric charge. If there are fewer electrons in an atom's valence orbit than there are spaces left for additional electrons, the atom can easily lose the electrons. Such an element is a conductor. The fewer the electrons in its valence orbit, the better a conductor the element is. Copper, gold, and aluminum are good conductors.

Insulators—Substances that prevent the passage of an electric charge. When an element's valence orbit is close to being full, and there are more electrons in its valence orbit than there are spaces left for additional electrons, a much stronger electromotive force is needed to move the electrons. This type of element is called an insulator. The fuller the atom's valence orbit, the better an insulator the element is. Rubber, glass, and certain plastics are good insulators.

Semiconductors—Substances that neither transmit an electric charge well nor prohibit the passage of an electric charge well. Elements that have the same number of electrons in their valence orbit as they have spaces for electrons are neither good conductors nor good insulators. Such elements are called semiconductors. Carbon, silicon, and germanium are all semiconductors.

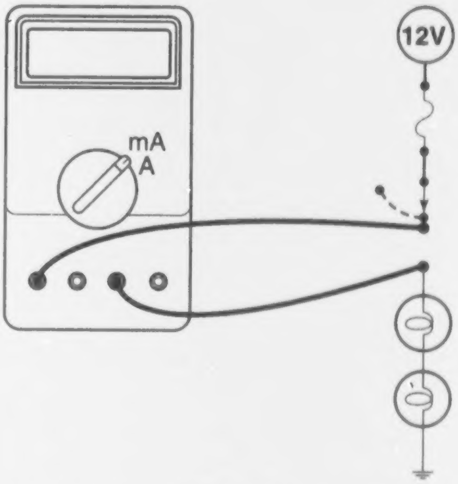
Student Supplement 3—Current, Voltage, and Resistance

Current

When an electromotive force is applied to a conductor, a flow of electric charge moves through the conductor. This flow is called current. How much current flows through a conductor depends upon two factors—the conductor itself and the strength of the electromotive force.

The amount of current flowing through a conductor is measured in amperes (amps)— a unit measuring electric current in terms of the number of electrons that pass by a given point in the conductor per second. To measure amps, a measuring device called an ammeter is connected directly to the conductor. (Figure 1)

Figure 1



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AC and DC Current

A vehicle's battery generates and stores only direct (DC) current. In electrical/electronic systems the current flows in one direction. Most batteries deliver DC current at a constant 6 or 12 volts, although some vehicles use 24 volts.

The vehicle's alternator produces only alternating (AC) current. Alternating current flows first in one direction and then in the opposite direction—fluctuating between a positive charge and a negative charge. Because it is created using magnetic means, AC current is easy to produce, but it has very limited uses in vehicles, and it is impossible to store. For these reasons, alternators have special circuits that convert the AC current into DC current so it can be used in automotive circuits and stored in the vehicle's battery. The advantage of AC current lies in the fact that it can be transported for long distances using power lines. Ordinary household current is alternating current.

Student Supplement 3

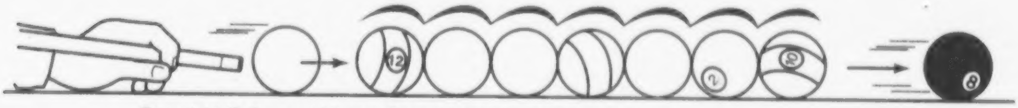
Voltage

How much current flows through a conductor depends upon two factors—the conductor itself and the strength of the electromotive force. The electromotive force, commonly called voltage, is the difference in electrical charge between the source of the voltage (usually the positive terminal of the battery) and the ending point of the conductor (usually the negative terminal of the battery) which is always presumed to be zero. Voltage is the force that starts and maintains the flow of electric current. The greater the voltage, or electromotive force, the greater will be the amount of current being conducted.

It is sometimes useful to think of voltage as electrical pressure. Unless voltage is applied to a conductor, electric current will not flow. For this reason voltage is referred to as potential force. Potential, voltage, electrical pressure, and electromotive force (EMF) all mean the same thing.

To return to the comparison used in Supplement 2 in which the force of a blow is transmitted to a line of pool balls: a player can use a cue stick to strike the line of pool balls. (Figure 2)

Figure 2



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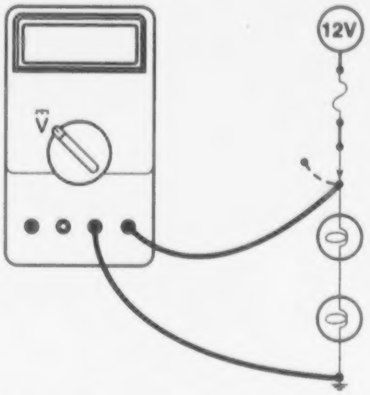
The player represents a source of voltage. When the player strikes the line of balls with the cue stick, the voltage is applied to the conductor. How hard the player (voltage) strikes the first ball in the line (end of the conductor) determines how much force (current) is transmitted down in the line of balls (conductor). The player can hit the balls hard (high voltage) or the player can hit the balls lightly (low voltage). This is where the comparison becomes inaccurate. Unlike a player, who can change the amount of force he or she uses, an automotive battery, when connected to a conductor, always transfers its full force to the conductor.

If the player (voltage) does not hit the line of balls (conductor) with the cue, no force (current) will be transmitted to the line of balls, just as no current will be started in the conductor if the voltage is not connected to the conductor. The player is still a source of energy even though he or she does not hit the line of balls—just as a battery is still a source of voltage even though it is not connected to a conductor.

Voltage is measured in volts. A single volt is the electrical charge necessary to push one ampere of electrical current through one ohm of electrical resistance. One volt is able to push a certain number of electrons past a given point in a conductor; two volts twice as many and so on. Voltage is measured by a voltmeter, which is connected to two points. (Figure 3)

Figure 3



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As you will learn in Supplement 5, voltage can be created by a number of different sources such as heat, light, pressure, friction, motion, chemical action, or magnetism.

Several of these sources produce very tiny amounts of voltage to carry out the specific functions of certain electrical components. However, the two sources of voltage for electrical and electronic systems in a vehicle are the battery and the alternator.

Resistance

How much current flows through a conductor depends upon two factors—the conductor itself and the strength of the voltage. You learned that when voltage is increased the amount of current increases. But another factor also affects the amount of current transmitted through a conductor: resistance.

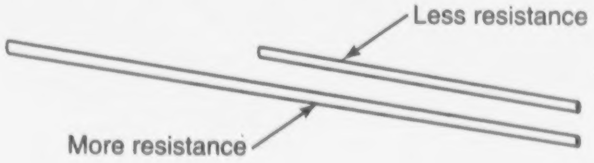
Resistance is opposition to the flow of current in a conductor. All materials, even the best conductors, contain some resistance, and resistance always decreases the amount of current moving through a conductor. If resistance increases, the amount of current decreases; if resistance decreases, the amount of current increases.

Several factors determine the amount of resistance in a conductor:

- **The type of material conducting the current**—In Supplement 2 we discussed what makes an element a good conductor. Some conductors, of course, are not made from a single element, but from compounds containing several elements. Some conductors are not even elements or compounds, but are components constructed of several different materials. And some conductors—whether they are elements, compounds, or components—have more resistance than others.

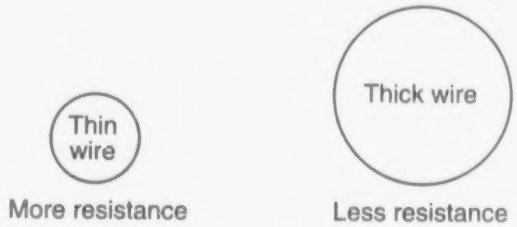
- **The length of the conductor**—This factor, for obvious reasons, applies mostly to wire, but it is equally applicable to any conductor. Even if the current flows through an excellent conductor, resistance is greater if the distance the current must travel is greater. The longer the wire, the more the resistance—the shorter the wire, the less the resistance. (Figure 4)

Figure 4



- **The diameter of the conductor**—Thick wire provides less resistance than thin wire. In a thicker conductor, the current has a wider area through which it can pass, making the energy transfer easier. (Figure 5)

Figure 5

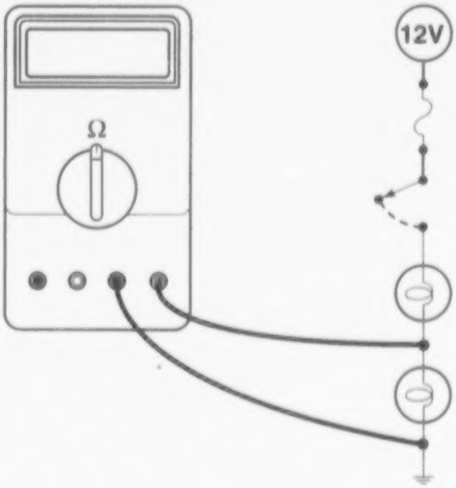


- **The temperature of the conductor**—Resistance is lower in materials that are cooler. For most materials the higher the temperature, the higher the resistance. There are, however, a few materials—such as non-metals—whose resistance goes down as the temperature goes up.

- **The physical condition of the conductor**—A cut, nicked, kinked, or corroded conductor has a higher resistance to current.

Resistance is measured in ohms (Ω) by a special meter called an ohmmeter. (Figure 6) When writing measurements, the term ohm is abbreviated by using the Greek letter Omega (Ω). One ohm allows one amp of current to flow when one volt is applied to a conductor.

Figure 6



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Whenever current passes through resistance in a conductor, two things happen:

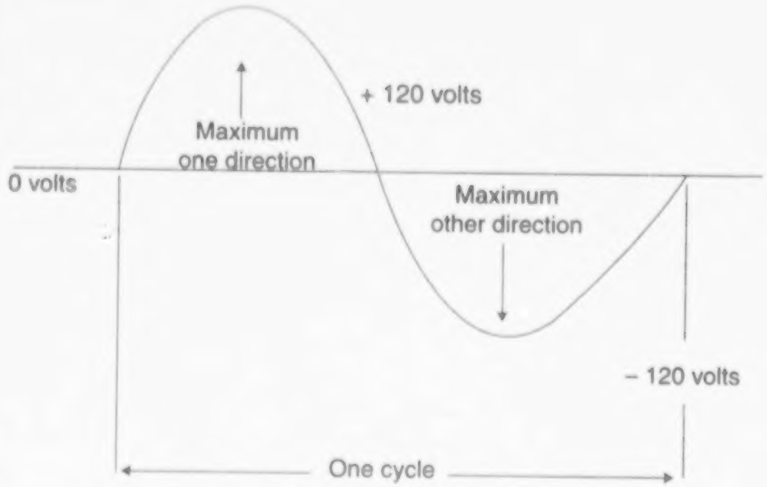
- Voltage always drops after encountering resistance.
- Some of the electrical energy changes to another form of energy such as heat, light, or motion when encountering resistance.

  Note: Sometimes current is directed into a component with high resistance just so the resistance will change the electrical energy into another form of energy. (A cigar lighter and a window deicer filament are examples of resistance used in this way.)

Frequency

The time taken for such an alternation to go through one complete cycle of change, from zero, through maximum in one direction, back through zero to maximum in the other direction and finally back to zero again, is called a *cycle*. The rate at which cycles occur within a specified time period is called the *frequency*. The common used unit of frequency measures the number of cycles every second, and the figure obtained is given the name *Hertz* (abbreviated Hz).

Figure 7



Voltage Drop

Voltage drop is the voltage lost or consumed as current moves through resistance. Voltage is highest where the conductor connects to the voltage source, but decreases slightly as it moves through the conductor. If you measure voltage before it goes into a conductor and measure it again on the other side of a conductor, you will find that the voltage has decreased. This is voltage drop. When several conductors are connected to each other (as in a circuit), the voltage will drop each time the current passes through another conductor.

Imagine the line of pool balls and the blow from the cue stick. Ask yourself, "Which blow is harder — the blow from the pool cue or the force from the ball at the end of the line?" Obviously the blow from the cue will be stronger than the blow from the ball at the end of the line. Why? Because the individual balls in the line (the conductors, each of which has resistance) have each absorbed some of the energy (voltage). The more resistance the energy must travel through, the less energy is available at the end of the conductor. If you make the line of balls even longer, the last ball in line will travel a shorter distance away from the line because less energy will be available to transfer into motion. Each ball absorbs some of the energy, and the amount of available energy (voltage) will go down (drop) after tne energy travels through each ball (resistance).

Student Supplement 4—Ohm's Law

Ohm's Law: *It takes one volt of electrical force to push one ampere of electrical current past one ohm of electrical resistance.*

Rarely will your success as a service technician depend on understanding a single principle. But this is that rare case. Electrical Systems Technicians must understand Ohm's law.

Diagnosing problems involving electricity is almost totally dependent upon your being able to use a multimeter. But you won't even be able to hook up a multimeter correctly if you don't understand Ohm's law. And if by chance someone hooks it up for you, you won't be able to use the measurements you read to determine what the problem is unless you understand Ohm's law. It's that simple.

What Ohm's Law Does

Ohm's law does three important things—two of these things you must know and remember, but the third thing you don't have to know. (The third thing is very important, but it'll work even if you don't know it.*) Electrical Systems Technicians use their knowledge of Ohm's law every day, and they use it from memory—this isn't something you can look up in a book; you use it too often for that.

Two useful things Ohm's law does:

1. It summarizes the effect voltage and resistance have on current.
2. It gives a formula you can use to calculate either:
    - The amount of current,
    - The amount of voltage, or
    - The amount of resistance

    in a conductor IF you know the value of the other two.

Summarizing the Effect Voltage and Resistance Have On Current

Use of Ohm's Law #1:

When thinking about the effect voltage and resistance have on current, there are two helpful things to keep in mind:

- Both voltage and resistance affect current.
    - — If the voltage in a conductor increases or decreases, the current will increase or decrease.

- If the resistance in a conductor increases or decreases, the current will decrease or increase.

- Current never changes on its own—it changes only if voltage or resistance changes.

Note: Current cannot change on its own because current is caused by voltage (volts) flowing through a conductor, and all conductors have resistance—ohms. The amount of current can change only if the voltage or the conductor changes.

If the voltage increases, the current increases—provided the resistance stays the same.

If the voltage decreases, the current decreases—provided the resistance stays the same.

I — Current	E — Voltage	R — Resistance
Increases ↑	Increases ↑	**Stays the Same**
Decreases ↓	Decreases ↓	**Stays the Same**

If the resistance increases, the current decreases—provided the voltage stays the same.

If the resistance decreases, the current increases—provided the voltage stays the same.

I — Current	E — Voltage	R — Resistance
Decreases ↓	**Stays the Same**	Increases ↑
Increases ↑	**Stays the Same**	Decreases ↓

The relationship between voltage, resistance, and current can be summarized by the following chart. This chart can be used to predict the effect of changes in voltage and resistance or to predict the cause of changes in current.

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I — Current (Amps)	**E — Voltage (Volts)**	**R — Resistance (Ohms)**
Increases ↑	**Increases ↑**	Stays the Same
Increases ↑	**Increases ↑**	Decreases ↓
Stays the Same	**Increases ↑**	Increases ↑
Decreases ↓	**Decreases ↓**	Stays the Same
Stays the Same	**Decreases ↓**	Decreases ↓
Decreases ↓	**Decreases ↓**	Increases ↑
Decreases ↓	Stays the Same	**Increases ↑**
Decreases ↓	Decreases ↓	**Increases ↑**
Stays the Same	Increases ↑	**Increases ↑**
Increases ↑	Stays the Same	**Decreases ↓**
Stays the Same	Decreases ↓	**Decreases ↓**
Increases ↑	Increases ↑	**Decreases ↓**
Increases ↑	Stays the Same	Decreases ↓
Increases ↑	Increases ↑	Stays the Same
Increases ↑	Increases ↑	Decreases ↓
Decreases ↓	Stays the Same	Increases ↑
Decreases ↓	Decreases ↓	Stays the Same
Decreases ↓	Decreases ↓	Increases ↑

Notice that in addition to showing what happens to current if voltage or resistance changes, the chart also tells you the most likely result if both voltage and resistance change.

Note: If current "stays the same" but both voltage and resistance increase or both decrease, then the increase or decrease will be proportional.

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Calculating the Value Of Current, Voltage, and Resistance

Use of Ohm's Law #2:

In addition to summarizing the effect voltage and resistance have on current, Ohm's law also gives a mathematical formula you can use to calculate the values of current, voltage, and resistance.

The formula is $\mathbf{I = \frac{E}{R}}$ or put in words: $\mathbf{Amps = \frac{Volts}{Ohms}}$

The important thing to remember is that in order to calculate the value of current, voltage, or resistance, you must know the value of two of the three (current, voltage, and resistance).

To calculate: you must know:	amps (current), volts (voltage) and ohms (resistance).
To calculate: you must know:	volts (voltage), amps (current) and ohms (resistance).
To calculate: you must know:	ohms (resistance), volts (voltage) and amps (current).

To calculate the amount of current (amps) in a conductor, you use this formula:

$$I = \frac{E}{R} \qquad \text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

The number of amps equals the number of volts divided by the number of ohms.

Example: If 12 volts are applied to a conductor that has a resistance of 2 ohms, how many amps will be measured in the conductor?

$$I = \frac{12}{2} \qquad \text{Amps} = \frac{12}{2} = 6 \text{ amps}$$

To calculate the amount of voltage (volts) in a conductor, you use this formula:

$E = I \times R$ Volts = Amps x Ohms

The number of volts equals the number of amps multiplied by the number of ohms.

Example: What is the voltage in a conductor if the current is 4 amps and the resistance is 3 ohms?

$E = 4 \times 3$ Volts = 4 x 3 = 12 volts

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To calculate the amount of resistance (ohms) in a conductor, you use this formula:

$R = \frac{E}{I}$ Ohms = $\frac{\text{Volts}}{\text{Amps}}$

The number of ohms equals the number of volts divided by the number of amps.

Example: What is the resistance in a conductor if 12 volts is applied and the current is 6 amps after passing through the conductor?

$R = 12 \div 6$ Ohms = $\frac{12}{6} = 2$ ohms

* The mysterious third thing Ohm's Law does: It sets the value of amps, volts, and ohms in their relationship to each other.

It takes one volt of electrical force to push one ampere of electrical current past one ohm of electrical resistance. Their relationship is a 1:1:1 ratio.

Georg Ohm (1789-1854) could have decided that "It takes 1.3 volts of electrical force to push 6.27 amperes of electrical current past .765 ohms of electrical resistance." Aren't you glad he didn't?

Student Supplement 5—Energy and Electricity

Energy

In our everyday lives, we are used to using the word energy to mean "using power to do work (or play)," usually something we can see happening. A car moves, a runner jogs, a carpenter hammers a nail, an electric mixer beats a batter. We can see energy in these actions. But like many words, the word energy doesn't have just one definition, it has other meanings as well.

Energy doesn't mean just using power to do work. Energy also means the capacity to do work, the potential to do work. When you think of energy using this definition, you can see that energy comes in many forms, some of which you can't even see. Light is energy, matter is energy, heat is energy, gravity is energy, motion is energy, electricity is energy, and so forth. They're all just different forms of energy.

And the really interesting thing is that you can use one form of energy to create energy (or release the energy) in another form.

When you use the composition, structure, properties, and reactions of matter to create energy, you are creating energy by chemical means. If you apply a flame to wood, it will burn, releasing a much larger amount of heat energy from the matter which makes up the wood. This is an example of creating energy by chemical means. If you combine certain types of matter in specific, precise ways, as is done in a battery, you can use those substances to create electrical energy; this is also creating energy by chemical means.

You can use the motion of falling water (matter influenced by gravity) to turn a water wheel and use that motion to grind grain as they did years ago. Or you can use the motion of falling water to turn an electric generator in a huge dam to create electricity which you can move about the country through power lines to do work in homes and factories.

In fact that is what makes electric current so useful. It can be created easily from many other forms of energy and easily transported directly to where it's needed. But remember, electricity is a form of energy. It's not actual movement or force you can see, it's potential to do work. Electric current is not actual movement being transmitted through electric wires and components, it's energy—potential to do work.

Of course, if you are careless enough to touch an uninsulated wire which is carrying electricity, you will experience that potential energy being changed into other forms of energy—a shock which will cause intense heat that will burn you and violent muscle spasms (motion) that you will definitely feel. If the strength of the electricity in the wire is strong enough, the electric current will also disrupt and damage the normal electrical impulses in your brain and the normal electrical impulses that keep your heart beating. Interesting, but highly discouraged.

Warning: Touching an uninsulated wire is extremely dangerous and could be fatal. Always verify that the circuit is disconnected from the power source before handling an uninsulated wire.

Sources of Electricity

A number of different sources, such as motion, heat, light, pressure, friction, chemical action, or magnetism, can create the electromotive force, commonly known as voltage, which creates electric current.

- A generator is the common term for a device that produces voltage from mechanical energy. The most common generators produce voltage from falling water (as in a dam) and steam (power plants fueled by coal or nuclear power). Portable generators produce voltage from gasoline. The alternators found in vehicles use both the mechanical energy produced by the engine and magnetism to produce voltage.
- Some materials create an electromotive force when they're exposed to light. Voltage produced in this way is an example of generation from a photovoltaic source; headlamp sensors use this property in their operation. Solar power is a familiar example of voltage produced from light.
- When some materials are heated, voltage is produced. Voltage produced directly by heat has a thermoelectric source.
- A few materials, such as crystals, will generate voltage when placed under pressure. Voltage created through the application of pressure is from a piezoelectric generator.
- When two materials are rubbed together, friction can release some electrons, creating an electromotive force. A spark can occur when the charged material is brought near a material with no charge. This type of voltage, generated by friction, is electrostatic in origin. Service technicians must constantly be on guard against static electricity, especially when working around electronic components that can be easily damaged by even the relatively small amounts of static electricity generated under normal working conditions.
- Batteries are an electrochemical source of voltage; they use chemical action to produce voltage. In a battery, sulfuric acid and two kinds of metal are used to generate voltage. Batteries have the advantage of being able to generate and store amounts of voltage in quantities sufficient for most electrical uses.
- A vehicle's alternator is an example of using electromagnetism to help produce voltage. It uses electromagnetic means to transform the mechanical energy created by the vehicle's engine into electrical energy.

Student Supplement 6—Magnets

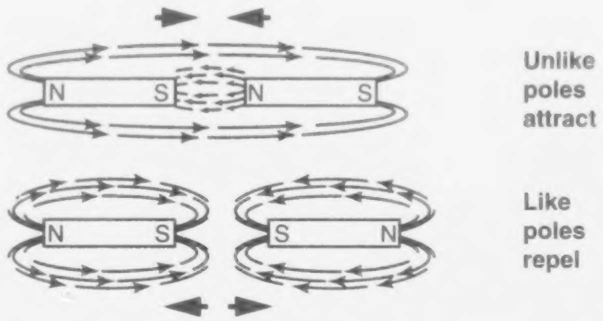
Magnets are used in many ways, from pinning a note to a refrigerator door to storing all the information in a computer. Magnets are objects that are surrounded by a magnetic field and have the capacity to attract certain materials. Magnetism is the force exerted by magnets. Even though magnetic forces are invisible, you can see their effects and the actions they cause. All magnets behave in the same ways and have the same effects on objects around them.

The most obvious property of magnets is announced in the definition of magnets: magnets attract certain materials and any substance that contains these materials. Iron, steel, nickel, and cobalt are a few of the materials that are attracted by magnets. Although most materials capable of being attracted by a magnet are metals, not all metals are attracted. Some metals, such as aluminum, are not attracted by magnets at all. In fact, many substances (such as wood, glass, and plastic) are not attracted by magnets. Such materials are said to be non-magnetic, while materials that are attracted by magnets are called magnetic. If an object is attracted by a magnet, you can be sure that the object has—at least some of—one of these magnetic materials in it. The word magnetic applies both to magnets themselves and to materials capable of being attracted by a magnet. Sometimes this can be confusing.

Polarity

Both ends of every magnet will attract magnetic objects. And if you only have one magnet, you might never know that both ends of the magnet are not exactly the same. But if you do have another magnet, you can see the difference between the two ends.

Figure 1



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If you bring one end of the first magnet together with one end of the second magnet, the two magnets will either repel each other or they will attract each other. (Figure 1) If you then turn the first magnet around and try to bring its other end to the end of the second magnet, you will find that these two ends do exactly the opposite. If the magnets were attracted at first, they will now be repelled; if they were repelled at first, they will now be attracted. This magnetic behavior is called polarity.

To keep track of this difference between the two ends of a magnet, one end of a magnet is called the south (S) pole and the other is called the north (N) pole. All magnets have polarity and demonstrate this unique behavior:

- Like poles (N-N or S-S) repel each other.
- Unlike poles (N-S) attract each other.

Look at Figure 1 again. Notice that the black lines with arrows which show where the magnetic forces operate extend not only to a nearby magnet (as shown in the top illustration), but also to the other end of the magnet itself.

This is important to note. Even though the power of a magnet is only observable when a magnet is near a magnetic substance, the magnetic field exists at all times—even if another magnetic substance is not present. If no other magnetic substance is near the magnet, the polarity of the magnet operates on the opposite end of the magnet itself. The pole on one end of the magnet attracts the unlike pole on the other end of the magnet. In fact, as you can see, even if another magnet is near, the unlike pole on the far end of one magnet attracts the unlike pole on the far end of the other magnet.

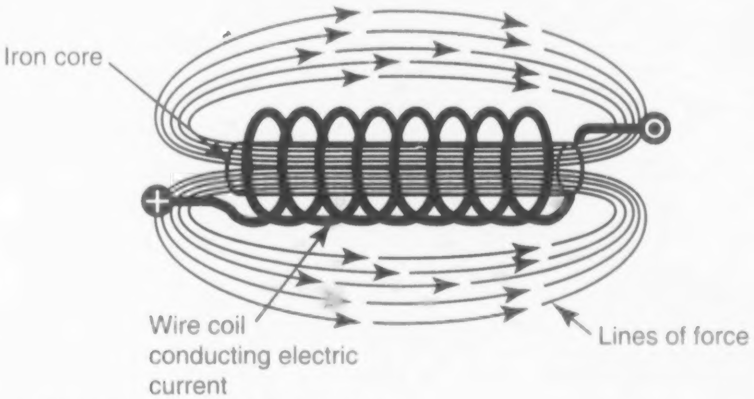
Interestingly, if you cut a magnet in half, the two pieces of the magnet will also have two poles. No matter how many times or how small you divide a magnet, every—even tiny—piece will have polarity.

Kinds of Magnets

There are three kinds of magnets: natural magnets, permanent magnets, and electromagnets.

- **Natural magnets** are magnetic materials that occur naturally. Some rocks and small stones (such as magnetite and lodestone) contain minerals with natural magnetic properties. These rocks will attract magnetic materials just like a man-made magnet.
- **Permanent magnets** are man-made magnets that keep their magnetic properties indefinitely. Permanent magnets are made by putting hard magnetic materials into a very strong magnetic field. Soft metals can be made into magnets too, but their magnetic properties don't last very long. You can make permanent magnets in many shapes and sizes. Common shapes are bar magnets and horseshoe magnets.

Figure 2



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- **Electromagnets** (Figure 2) are made by surrounding a soft iron core with a coil of wire that is conducting electric current. Electromagnets are man-made too, but they only have magnetic properties while electricity is flowing through the wire coil that surrounds them. If the electricity in the coil is turned on, the iron core is a strong magnet. When the electricity is turned off, the core loses its magnetic properties. Electromagnets and their magnetic properties have very important uses, but to understand how they work, you must first know a little more about magnetic properties in general.

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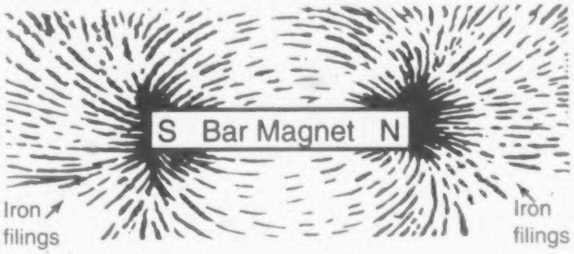
Student Supplement 7—Magnetism and Electricity

Magnetic Fields and Magnetic Flux

Magnetic force is invisible. We know it exists only by the effects it produces. If you hold a pin near a magnet, you can see and feel the magnet attracting the pin. This space around a magnet where the force of the magnet can be detected is called a magnetic field. A magnetic field is strongest close to the magnet and is weakest farther away. If you place a piece of paper over a bar magnet and sprinkle iron filings on top of the paper, you can see the magnetic field of the bar magnet beneath. (Figure 1)

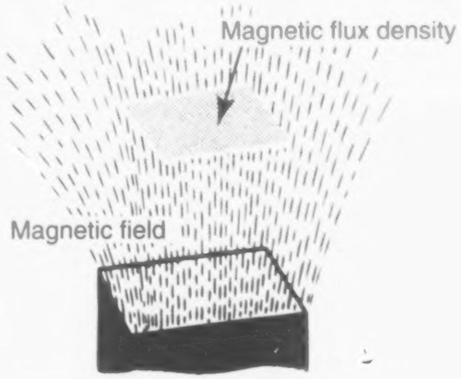
Figure 1



The lines of filings you see in Figure 1 also illustrate another characteristic of magnets—flux lines. Flux lines are imaginary lines that define a magnetic field. They are closest together near the poles of the magnet where the magnetic force is strong and further apart where the magnetic force is weaker. Flux lines are continuous, unbroken, and do not cross each other. The shape and space flux lines occupy is called a flux pattern.

The number of flux lines in an area is called flux density. (Figure 2) The stronger the magnetic field, the greater the flux density.

Figure 2



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A magnetic field differs from magnetic flux. A magnetic field defines the area in which the magnetic forces operate. Magnetic flux defines the strength of the magnetic force operating in the magnetic field.

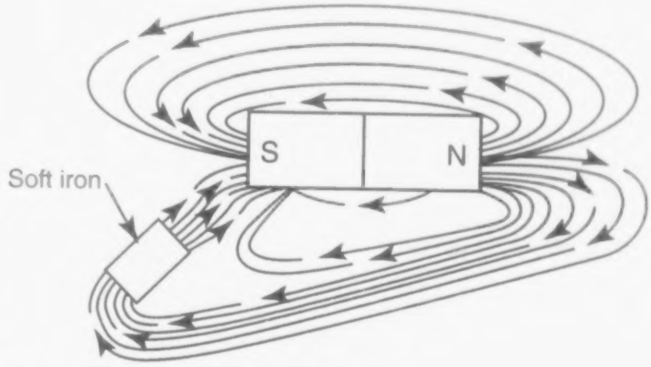
Magnetic Permeability and Magnetic Reluctance

You cannot insulate magnetic lines of force. If the flux lines are dense enough, they will pass through anything. But magnetic force passes through some substances more easily than through others. How easily magnetic force passes through a substance is called its magnetic permeability. Flux lines pass through iron more easily than they do through air. Iron has a high magnetic permeability; air has a low magnetic permeability.

Just as some substances let magnetic forces pass through more easily than others, some substances are reluctant to pass flux lines. Materials that are reluctant to pass magnetic lines of force have a high magnetic reluctance. Air has a high magnetic reluctance; iron has a low magnetic reluctance.

Figure 3 illustrates magnetic reluctance. Even though the bar of soft iron is some distance away from the bar magnet, the flux lines of the bar magnet travel that distance to flow through the iron because the iron has a lower magnetic reluctance than the air closer to the magnet.

Figure 3



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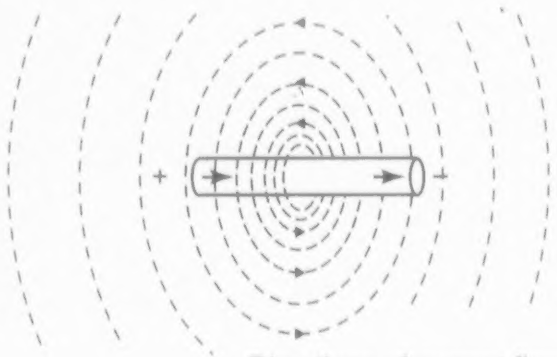
It is hard to imagine that it is easier for a strong force like magnetism to move further away to go through a piece of metal than it is for the magnetism to merely move through what appears to us to be “nothing” closer by. But in fact that “nothing” is really air, and magnetism doesn't pass through air as easily as it does through iron.

Electromagnetism

Magnetic force can be created by electric current. Whenever a wire or any conductor is conducting electricity, a magnetic field is created that surrounds the wire or conductor and extends at a right angle from it for the wire or conductor's entire length. (Figure 4) When the current stops, the magnetic field collapses and the conductor's magnetic properties vanish.

Figure 4

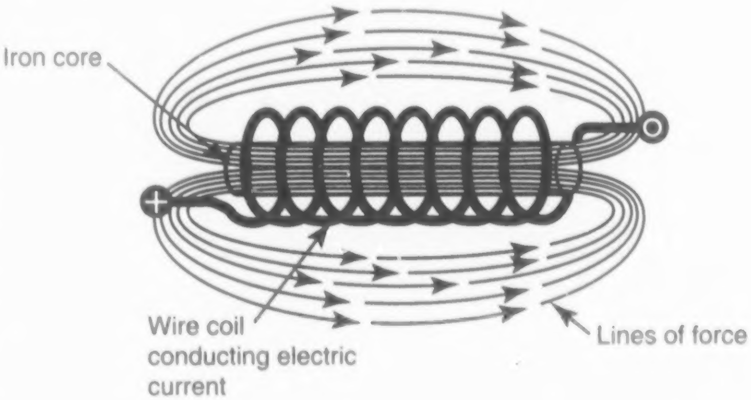


Directions of current flow

Unlike current, this magnetic force is not insulated by any "insulation" which normally covers the wire. (See magnetic permeability.) Magnetic energy produced by wires and other components carrying current for use in automotive electric systems is unintentional.

If you increase the current flowing through a wire, the wire's magnetic field will become stronger. If the wire is coiled around a soft iron core, the flux lines of the magnetic field created by the current can be concentrated into a small area, and the magnetic powers induced in the iron core will be very strong. An electromagnet created in this way (Figure 5) will be very strong indeed.

Figure 5



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The strength of the electromagnet can be increased both by increasing the number of coils around the core and by increasing the current flowing in the coiled wire.

Electromagnets are particularly useful for vehicle purposes because, unlike natural or permanent magnets:

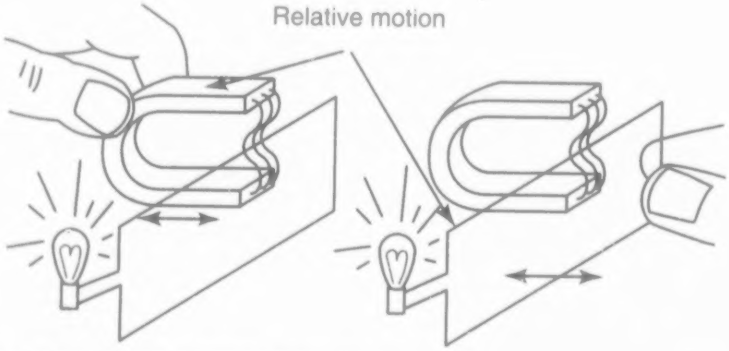
- They can be turned on and off.
- The strength of their magnetic force can be adjusted.
- They can achieve a very high level of magnetic force—very much higher than natural or permanent magnets.
- They have the ability to increase, decrease, and control electric voltage using electromagnetic induction.

Electromagnetic Induction

When a paper clip, or any small piece of iron or steel, is attracted to a magnet, the paperclip itself becomes a magnet. And that paperclip can attract a second paperclip; and the second paper clip can attract a third, and so on... This process by which a substance, such as iron or steel, becomes magnetized by a magnetic field is called magnetic induction.

Magnetic force can create electric current. Just as electrical energy can create magnetic force, magnetic force can create electrical energy. If a magnetic field is moved back and forth over a wire (or any conductor), voltage will be created in the wire (Figure 6, left). Or, if a wire is moved back and forth inside a magnetic field, voltage will be created (Figure 6, right). The process of creating voltage using magnets is called electromagnetic induction.

Figure 6



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The strength of the induced voltage depends on the rate at which the flux lines of the magnetic field are cut. The more flux lines cut per unit of time, the greater will be the voltage produced.

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Objective 25

Assignment Sheet 1—Calculate Current Using Ohm's Law

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Completed all problems and showed work	______
• Labeled answers with correct term	______
• Answered a minimum of 12 of the 15 questions correctly per Assignment Sheet 1 answers.	______

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

Any change in current is a result of increased or decreased voltage or increased or decreased resistance. Current does not change unless voltage and/or resistance changes.

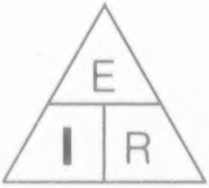
If there is not enough current in a circuit, electrical or electronic components in the circuit will not function properly; a motor might run too slowly or a bulb burn dimly. If there is too much current, circuit components can overheat or burn up, destroying them.

The formula for calculating current is:

> The number of amps is equal to the number of volts divided by the number of ohms.

There are several ways to say the same thing:

- $I = \frac{E}{R}$
- Current is equal to voltage divided by resistance.
- $\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$
- $\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$
- $A = \frac{V}{\Omega}$



Assignment Sheet 1

Directions

Review and use the information found in the Information Sheet, Objectives 15 and 16, Student Supplement 3, *Current, Voltage, and Resistance*, and Student Supplement 4, *Ohm's Law* to answer the following questions. Write your answer in the blank provided. Remember to use the correct term to identify your answer. Don't just put "1.4;" put "1.4 amps" or "1.4 A." Show your work.

_______ 1. If the voltage in a circuit is 12 V and the resistance is 6Ω, what is the current?

$I = \frac{12}{6} =$

_______ 2. What is the current measurement on a circuit using 12 volts with 8 ohms of resistance?

I = _______________ =

_______ 3. The resistance in a circuit is 30 Ω at 12 volts, what are the amps?

_______ 4. If E = 6 V and R = 2.5 Ω, what is I?

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________ 5. Resistance in a circuit is 60 Ω and the voltage is 12 V. Calculate the current.

________ 6. If a circuit is using 6 volts and has .9Ω of resistance, what is A?

________ 7. Calculate the current in a conductor with 40Ω if 12 V is applied.

________ 8. If a circuit is using 12 volts has a resistance of .48 ohms, what will the current be?

________ 9. How much current is present in a conductor with 7.5 Ω and 24 V?

________ 10. What is A if Ω measures 9.33 at 12 volts?

Assignment Sheet 1

_______ 11. A circuit has a voltage of 6V and a resistance of 6Ω. What is the current reading?

_______ 12. How many amps are there in a conductor if there are 3.2 ohms and 12 volts?

_______ 13. Calculate the current in a circuit with 12 V and 4.76 Ω.

_______ 14. If a battery measuring 12 volts is applied to a circuit with 5.55 ohms, how many amps will be measured?

_______ 15. What is the current in a conductor with a resistance of 7.1 and a voltage of 6?

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Objective 26

Assignment Sheet 2—Calculate Voltage Using Ohm's Law

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Completed all problems and showed work	______
• Labeled answers with correct term	______
• Answered a minimum of 12 of the 15 questions correctly per Assignment Sheet 2 answers.	______

Basic Skills

Reading · Mathematics · Science · Critical Thinking

Introduction

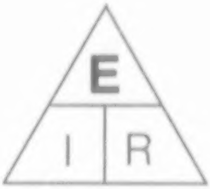
Ohm's law is a mathematical formula describing the relationship between current, voltage, and resistance in an electrical circuit. Using the formula for Ohm's law will allow you to calculate the value of current, voltage, or resistance if you know the values of the other two of the three (current, voltage, and resistance).

According to the formula for Ohm's law:

> The number of volts is equal to the number of amps multiplied by the number of ohms.

There are several ways to say the same thing:

- $E = I \times R$
- Voltage is equal to current multiplied by resistance.
- Voltage = Current x Resistance
- Volts = Amps x Ohms
- $V = A \times \Omega$



Assignment Sheet 2

Directions

Review and use the information found in the Information Sheet, Objectives 15 and 16, Student Supplement 3, *Current, Voltage, and Resistance*, and Student Supplement 4, *Ohm's Law* to answer the following questions. Write your answer in the blank provided. Remember to use the correct term to identify your answer. Don't just put "12;" put "12 volts," or "12 V." Show your work.

_________ 1. If the resistance in a circuit is three ohms and the current is two amps, what is the voltage?

E = 2 x 3

_________ 2. If the current is three amps and the resistance is eight ohms, how much voltage is applied to the circuit?

voltage = _______ amps x ________ ohms

_________ 3. If the resistance in a conductor is six Ω and the current is two A, what is the voltage? (It doesn't matter whether you write "ohms" or "amps" first, the answer will still be the same.)

V = ___________ ohms x ___________ amps

571

_________ 4. If a circuit has a current of 2 A and resistance of 12 Ω, how much is the voltage?

_________ 5. Calculate the voltage in a circuit of 6 Ω and 1 A.

_________ 6. If a circuit measures 2.4 amps and registers 5 Ω, what is the voltage?

_________ 7. If the resistance in a circuit is 4 ohms and the current is 1.5 A, what is V?

_________ 8. If a circuit has a current flow of 3.5 amps and a resistance of 3.4 ohms, how much is the voltage?

________ 9. What is V in a circuit that has 7.5 Ω and 1.6 amps?

________ 10. How many volts are in a circuit with 12 ohms and current at .5 amps?

________ 11. Calculate the voltage in a circuit with 9.6 Ω and 1.25 A.

________ 12. What is the voltage in a conductor of 3.3 ohms when the current is 1.82 A?

________ 13. If a circuit has a resistance of 15 Ω and current of .8 A, what is the voltage?

________ 14. What is the voltage in a conductor which measures 5.1 amps with 4.7 ohms of resistance?

________ 15. Calculate the voltage in a circuit of 4.11 Ω and 1.46 A.

Objective 27

Assignment Sheet 3—Calculate Resistance Using Ohm's Law

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Completed all problems and showed work	______
• Labeled answers with correct term	______
• Answered a minimum of 12 of the 15 questions correctly per Assignment Sheet 3 answers.	______

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

In vehicle electronics, a change in resistance is by far the most frequent signal that something is wrong in the circuit.

Think about it:

If the amount of current is not within specifications, either voltage or resistance could cause the bad measurement. Remember—current is caused by both voltage and resistance: it never just "changes on its own."

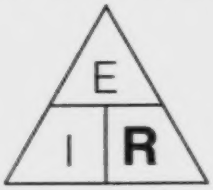
A vehicle's supply of voltage is constant from the battery—usually 12 volts. It might vary a little bit, but usually not much.

If the current doesn't change on its own, and voltage changes very little—what's causing inconsistent current readings? Usually something that's causing too much or too little resistance.

The formula for calculating resistance in a circuit is:

> The number of ohms is equal to the number of volts divided by the number of amps.

There are several ways to say the same thing:



- $R = \frac{E}{I}$
- Resistance is equal to voltage divided by current.

- Resistance = $\frac{\text{Voltage}}{\text{Current}}$
- Ohms = $\frac{\text{Volts}}{\text{Amps}}$
- $\Omega = \frac{V}{A}$

Directions

Review and use the information found in the Information Sheet, Objectives 15 and 16, Student Supplement 3, *Current, Voltage, and Resistance*, and Student Supplement 4, *Ohm's Law* to answer the following questions. Write your answer in the blank provided. Remember to use the correct term to identify your answer. Don't just put "7.2;" put "7.2 ohms" or "7.2 Ω." Show your work.

________ 1. If the current in a circuit using a 6-volt battery is 2 amps, what is the resistance?

$R = \frac{6}{2} =$

________ 2. If a circuit has 12 volts applied and current of 4 amps, what is the resistance?

$R = \frac{12}{4} =$

576

________ 3. What is the resistance in a conductor if th voltage is 12 V and the current is 30 A?

$$R = \frac{\text{volts}}{\text{amps}}$$

________ 4. If the voltage is 12 volts and the current is 8 amps, how many ohms is the resistance?

________ 5. If a circuit has 6 V applied and current of .25 A, what is Ω in the circuit?

________ 6. What is Ω in a conductor that has 2.5 amps at 12 V?

________ 7. How many ohms are in a circuit where 12 volts delivers 9 amps of current?

________ 8. At 6-volts, current is .05 A. What is the ohms measurement?

________ 9. A circuit carries a current of 10.0 amps on a 6-volt batter. How many Ω are in the circuit?

________ 10. A circuit using a 12-volt battery has current at 19 A. What should the Ω be in the circuit?

________ 11. The current is 2.4 A in a conductor supplied at 12 V. What is the resistance?

_______ 12. How many ohms are there in a circuit using 12 volts if there are 15 amps?

_______ 13. If E = 12 and I = .3, calculate R.

_______ 14. A circuit is supplied with a 6-volt battery and has a current of .375 amps. What is the resistance in the circuit?

_______ 15. A wire conducts 30 amps at 6 volts. What is its resistance?

Objective 28

Assignment Sheet 4—Predict Changes In Voltage, Current, and Resistance In A Circuit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Completed all problems and showed work	______
• Labeled answers with correct term	______
• Answered a minimum of 24 of the 30 questions correctly per Assignment Sheet 4 answers.	______

Basic Skills

Reading

Science

Critical Thinking

Introduction

Troubleshooting and diagnosing electrical circuits is different from troubleshooting and diagnosing other parts of a vehicle. Chances are that the electrical circuits and individual electrical components will look perfectly normal, even if you visually check every part of the circuit. Usually the only way you can tell what part of the circuit is bad is by checking it with a multimeter. But before you even hook up a multimeter, you will need to know whether you want to measure the current, the voltage, or the resistance, and what part of the circuit you suspect of being bad. Knowing these things involves predicting—Electrical Systems Technicians do a lot of predicting.

To predict changes in voltage, current, and resistance, you must understand Ohm's law. You also must understand what creates voltage and what makes it decrease or increase. You must understand resistance and what makes it increase or decrease. And you must understand the effect that decreasing or increasing voltage or increasing or decreasing resistance has on current.

Two helpful things to remember about the relationship between current, voltage, and resistance:

- Both voltage and resistance affect current. .
    - — If the voltage in a conductor increases or decreases, the current will increase or decrease.
    - — If the resistance in a conductor increases or decreases, the current will decrease or increase.

Assignment Sheet 4

- Current never changes on its own—it changes only if voltage or resistance changes.

  Note: Current cannot change on its own because current is caused by voltage (volts) flowing through a conductor (and all conductors have resistance—ohms). The amount of current can change only if the voltage and/or the conductor changes.

The following chart summarizes the relationships between voltage, resistance, and current. This chart can be used to predict the effect of changes in voltage, resistance, and current.

I— Current (Amps)	**E —Voltage (Volts)**	**R— Resistance (Ohms)**
Increases ↑	**Increases ↑**	Stays the Same
Increases ↑	**Increases ↑**	Decreases ↓
Stays the Same	**Increases ↑**	Increases ↑
Decreases ↓	**Decreases ↓**	Stays the Same
Stays the Same	**Decreases ↓**	Decreases ↓
Decreases ↓	**Decreases ↓**	Increases ↑
Decreases ↓	Stays the Same	**Increases ↑**
Decreases ↓	Decreases ↓	**Increases ↑**
Stays the Same	Increases ↑	**Increases ↑**
Increases ↑	Stays the Same	**Decreases ↓**
Stays the Same	Decreases ↓	**Decreases ↓**
Increases ↑	Increases ↑	**Decreases ↓**
Increases ↑	Stays the Same	Decreases ↓
Increases ↑	Increases ↑	Stays the Same
Increases ↑	Increases ↑	Decreases ↓
Decreases ↓	Stays the Same	Increases ↑
Decreases ↓	Decreases ↓	Stays the Same
Decreases ↓	Decreases ↓	Increases ↑

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Notice that in addition to showing what happens to current if voltage or resistance changes, the chart also tells you the most likely result if both voltage and resistance change.

Note: If the current "stays the same" but both voltage and resistance increase or both decrease, then the increase or decrease will be proportional.

The importance of understanding these relationships cannot be stressed enough.

Directions

Write the letter of the answer that you believe is most likely to happen in the blank provided.

____ 1. If you increase only the voltage in a circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 2. If you increase only the resistance in a circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 3. If you decrease only the voltage in a circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 4. If you decrease only the resistance in a circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 5. If you increase only the volts in a circuit, how will the amps be affected?

a. They will increase.
b. They will decrease.
c. They will stay the same.
d. It is not possible to predict from this information.

____ 6. If you increase only the ohms in a circuit, how will the amps be affected?

a. They will increase.
b. They will decrease.
c. They will stay the same.
d. It is not possible to predict from this information.

____ 7. If you decrease only the volts in a circuit, how will the amps be affected?

a. They will increase.
b. They will decrease.
c. They will stay the same.
d. It is not possible to predict from this information.

____ 8. If you decrease only the ohms in a circuit, how will the amps be affected?

a. They will increase.
b. They will decrease.
c. They will stay the same.
d. It is not possible to predict from this information.

____ 9. If you change the battery in a circuit from a 6-volt battery to a 12-volt battery, and that is the only change you make to the circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 10. In a circuit, if you replace a bulb that has 4 ohms of resistance with one that has 2 ohms of resistance, and that is the only change you make to the circuit, how will the current be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

____ 11. If you replace a wire in a circuit with a new wire that is twice as long, how will the resistance in the circuit be affected?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

_____ 12. If you replace a wire in a circuit with a new wire that is twice as long, how will the current in the circuit be affected if the voltage remains the same?

a. It will increase.
b. It will decrease.
c. It will stay the same.
d. It is not possible to predict from this information.

_____ 13. If the current in a circuit increases and the resistance remains the same, what has happened to the voltage?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

_____ 14. If the resistance in a circuit increases and the current remains the same, what has happened to the voltage?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

_____ 15. If the current in a circuit decreases and the resistance remains the same, what has happened to the voltage?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

_____ 16. If the resistance in a circuit decreases and the current remains the same, what has happened to the voltage?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

_____ 17. If the amps in a circuit increase and the ohms remain the same, what has happened to the volts?

a. They have increased.
b. They have decreased.
c. They have stayed the same.
d. It is not possible to predict from this information.

____ 18. If the ohms in a circuit increase and the amps remain the same, what has happened to the volts?

a. They have increased.
b. They have decreased.
c. They have stayed the same.
d. It is not possible to predict from this information.

____ 19. If the amps in a circuit decrease and the ohms remain the same, what has happened to the volts?

a. They have increased.
b. They have decreased.
c. They have stayed the same.
d. It is not possible to predict from this information.

____ 20. If Ω in a circuit decreases and A remains the same, what has happened to V?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 21. In a circuit, if you replace a 2 Ω bulb with a 5 Ω bulb, and A stays the same, what has happened to V?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 22. In a circuit, if you replace a bulb with 4 ohms of resistance with one that has 3 ohms of resistance and the current stays the same, what has happened to the voltage?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 23. If the current in a circuit increases and the voltage remains the same, what has happened to the resistance?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 24. If the volts in a circuit increase and the amps remain the same, what has happened to the ohms?

a. They have increased.
b. They have decreased.
c. They have stayed the same.
d. It is not possible to predict from this information.

____ 25. If the current in a circuit decreases and the voltage remains the same, what has happened to the resistance?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 26. If V in a circuit decreases and A remains the same, what has happened to Ω?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 27. If the amps in a circuit increase and the volts remain the same, what has happened to the ohms?

a. They have increased.
b. They have decreased.
c. They have stayed the same.
d. It is not possible to predict from this information.

____ 28. In a circuit, if you replace a wire with a new wire of the same length, but having a smaller diameter, what happens to the current if the voltage remains the same?

a. It increases.
b. It decreases.
c. It stays the same.
d. It is not possible to predict from this information.

____ 29. If A in a circuit decreases and V remains the same, what has happened to Ω?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

____ 30. If you change the battery in a circuit from a 12 V to a 6 V, and the current stays the same, what has happened to the Ω?

a. It has increased.
b. It has decreased.
c. It has stayed the same.
d. It is not possible to predict from this information.

Unit 2 Understanding Circuits & Circuit Devices

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3—Use Wire Color and Circuit Identification Codes to Locate Circuit Information 2-87
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1—Inspect, Test, and Replace Spike Suppression Diodes/Resistors 2-107

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify characteristics of circuits, circuit devices, and types of wiring diagrams, use wiring diagrams to locate information about circuits, predict changes in current, voltage, and resistance, and inspect, test, and replace spike suppression diodes/resistors. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to circuits and circuit devices to their definitions.
2. Label the six circuit elements on an illustration of a basic vehicle circuit.
3. Distinguish among four types of commonly used circuits.
4. List the two power sources for vehicle electrical circuits.
5. State why and where vehicle circuits are grounded.
6. Draw wiring diagram symbols that indicate a battery and a ground.
7. Distinguish among common control devices by their illustrations, wiring diagram symbols, current factor controlled, and the type of control each has on voltage or resistance in a circuit.
8. Distinguish among common protection devices by their illustrations and wiring diagram symbols.
9. List the size categories of blade fuses.
10. Explain how fuses, fusible links, and circuit breakers protect the circuits on which they are installed.
11. Distinguish among common loads by their illustrations, wiring diagram symbols, and the form of energy into which each converts current.
12. Describe how a device that is electronic is different from a device that is electric.
13. Define the terms P-type semiconductors and N-type semiconductors.
14. List advantages and disadvantages of using electronic devices in circuits.
15. Distinguish among common electronic circuit devices by their illustrations, wiring diagram symbols, and functions in a circuit.

Objective Sheet

16. Distinguish among common conductors by their illustrations and wiring diagram symbols.

17. Name four types of material that are commonly used as insulators in vehicle electrical systems.

18. Explain the purpose of a wire shield.

19. List three purposes of wiring hardware, and match the names of wiring hardware to illustrations of the hardware.

20. Match names of common circuit features to the wiring diagram symbols that represent the features.

21. Distinguish among types of wiring diagrams.

22. Explain what the color bands found on resistors represent, and use the color bands on a resistor to determine its resistance value. (Assignment Sheet 1)

23. Determine correct replacement fuses. (Assignment Sheet 2)

24. Use wire color and circuit identification codes to locate circuit information. (Assignment Sheet 3)

25. Use wiring diagrams to locate information about circuits. (Assignment Sheet 4)

26. Use your knowledge of electric/electronic theory and circuit devices to predict changes in current, voltage, and resistance in a series circuit. (Assignment Sheet 5)

27. Inspect, test, and replace spike suppression diodes/resistors. (Job Sheet 1)

Information Sheet

Objective 1

Terms and definitions

a. **Bi-metal**—Made of two dissimilar metals

b. **Composite**—A material made of two or more different substances

c. **Conductor**—Provides a pathway for current to move between the circuit elements

Examples: wires, connectors, frames, body, buss bars

d. **Contact**—A connection between two conductors that permits a flow of current

e. **Control device**—Starts, stops, or in some way controls the current in the circuit

Examples: switches, resistors, diodes, transistors

f. **Diaphragm**—A part that moves in response to pressure

g. **Doping**—The addition of another element or elements to a semiconductor to increase or decrease its ability to conduct current

h. **Electrical circuit**—The unbroken path through a series of connected electrical and/or electric elements where current travels from a power source to a ground

i. **Electrostatic discharge**—The release of electrons to another surface. Electrostatic discharge is sometimes called static electricity

j. **Filament**—A slender wire of tungsten, carbon, or other material, which, when current flows through it in a vacuum, is heated to a brilliant glow and produces light

k. **Fuse rating**—The maximum amount of current a fuse will conduct without melting

l. **Ground**—Accepts the current, providing the end point necessary to maintain the flow of current through the circuit

Examples: negative terminal of the battery, frame rail, body

m. **Load**—Uses the current to achieve the purpose(s) of the circuit

Examples: lamps, motor, heating elements

n. **Mercury**—A poisonous metallic element that is liquid at room temperature

o. **Monitor**—To check by means of an electronic receiver

p. **Pole**—The end of a switch where the wiper is connected

q. **Power source**—Provides the voltage for the circuit

Examples: battery, alternator, generator

r. **Protection device**—Disconnects the circuit from the voltage if the current reaches a level that will damage any of the circuit elements

Examples: fuses, circuit breakers, fusible links

s. **Resistance tolerance**—The percentage above or below its resistance value a resistor can vary and still operate correctly

t. **Sensor**—A device that converts physical quantities such as pressure, pressure differential, airflow, temperature and velocity to provide a measurable signal

u. **Splice**—A place where two or more wires have been joined by solder or compression device

v. **Throw**—The end of a switch that the wiper moves to contact

w. **Vacuum**—A space empty of matter/anything less than atmospheric pressure

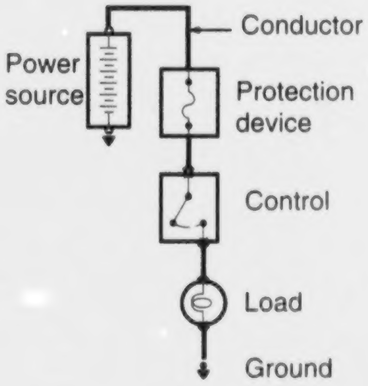
x. **Wiper**—A movable arm of a switch

y. **Wiring diagram**—A drawing that shows, in a simplified form, the position the circuit devices in an electrical circuit have in relation to each other

Objective 2

Six circuit elements on an illustration of a basic vehicle electrical circuit

Figure 1



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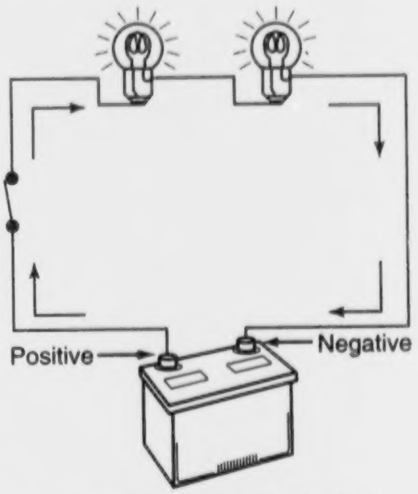
Objective 3

Four types of commonly used circuits

Note: The following diagrams illustrate the **Conventional Theory** of current flow.

a. **Series circuit**

Figure 2



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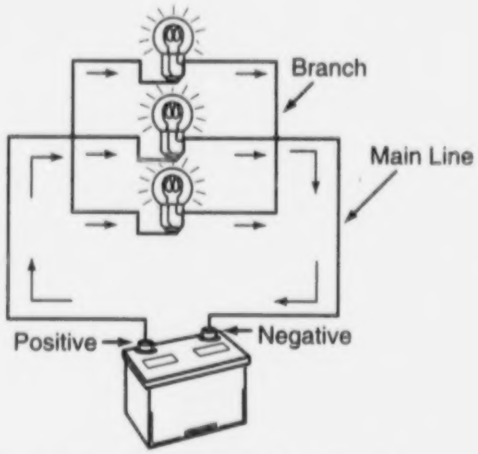
- One current path begins at the power source and ends at the ground.
- There is one or more load, control device, or protection device on its single path.
- The same current flows through every circuit element.
- A break anywhere on the single path stops the current to all the circuit elements.

b. **Parallel circuit**

Figure 3



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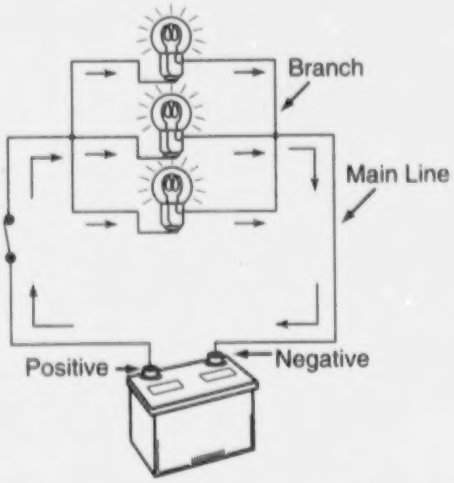
- One current path (called the *main line*) begins at the power source, divides into two or more paths (called *branches*), then reunites in a single path (again called the *main line*) to the ground.
- There is no load, control device, or protection device on the main line.
- There is one or more load, control device, or protection device on each branch.
- A break in one branch does not stop the current through other branches or the main line.
- A break in the main line stops the current to all circuit elements.

c. **Series-parallel circuit**

Figure 4



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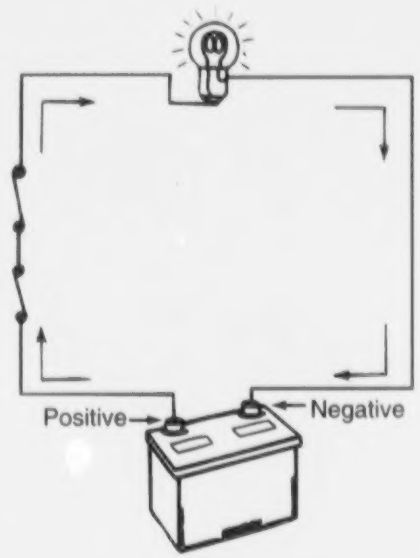
- One current path (called the *main line*) begins at the power source, divides into two or more paths (called *branches*), then reunites in a single path (again called the *main line*) to the ground.
- There is one more more load, control device, or protection device on the main line.
- There is one or more load, control device, or protection device on each branch.
- A break in one branch does not stop the current through other branches or the main line.
- A break in the main line stops the current to all circuit elements.

d. **Logic circuit**

Figure 5



Note: Logic circuits are made up of logic gates. They're called logic gates because they make logical decisions. They take voltage (analog) and turn it into a digital (logic) signal that processors understand (binary code).

- One current path begins at the power source and ends at the ground.
- There is one load, and two circuit or protection devices on its single path.
- The same current flows through every circuit element.
- A break anywhere on the single path stops the current to all circuit elements.

Objective 4

Two power sources for vehicle electrical circuits

a. Battery

b. Alternator/Generator

Note: These two power sources are the primary sources of voltage in vehicle electrical systems. Other devices (such as capacitors) may store and release small amounts of voltage, but they are not sources of voltage for the vehicle's electrical circuits.

Objective 5

Why and where electrical circuits are grounded

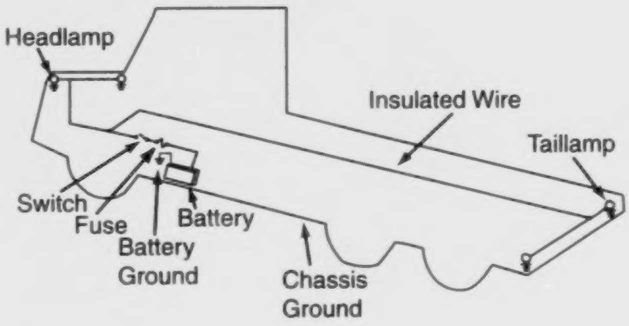
a. If a circuit is not grounded, current will not flow through it.

Note: In order for voltage to create current, there must be a difference in electrical charge between the source of the voltage (the positive terminal of the battery) and the ending point of the circuit. Grounding a circuit to the negative terminal of the battery provides this difference.

b. Most vehicle circuits are grounded to the negative terminal of the battery.

Note: Circuits in some vehicles are grounded to the positive side (electron theory) of the battery. This is usually available as an option.

Figure 6



Note: After the current in a vehicle circuit has been used to achieve its purpose (for example, illuminating the taillights), a wire from the circuit is screwed to the vehicle's body (or frame). From this point, the circuit's current flows through the body (and/or frame) to another screw and wire that connects the body to the battery's negative terminal. The vehicle's body (and/or frame) thus becomes part of every circuit as current flows from these grounding terminals through the body, returning to the battery.

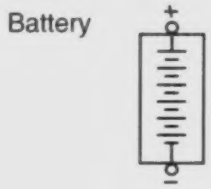
Information Sheet

Objective 6

Wiring diagram symbols that indicate a battery and a ground

a. Battery

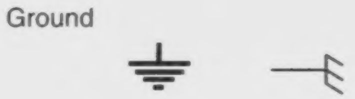
Figure 7



Note: Unfortunately, symbols that represent various circuit devices and features on wiring diagrams are not standardized in the trucking industry. Although some circuit devices are routinely symbolized by a single symbol, other circuit devices may be represented by several different symbols, depending upon the manufacturer. Individual vehicle manufacturers, however, usually standardize the symbols they use. **The symbols given in this curriculum are representative. They are not the only wiring diagram symbol in use for a circuit device or feature.**

b. Ground

Figure 8



Note: The symbol on the left is the one you most commonly see. However, the symbol on the right is the one that has been accepted as the industry standard.

Objective 7

Common control devices, their illustrations, wiring diagram symbols, current factor controlled, and the type of control each has on voltage or resistance in a circuit

Note: The examples of circuit devices in this unit are chosen because they are control devices, protection devices, loads, and conductors that are commonly found in most vehicles. The lists we have provided here are not comprehensive lists of all possible circuit devices. Additionally, many of the circuit devices pictured will come in various shapes and sizes, depending upon such variables as the manufacturer, the location where the devices are installed, and what other circuit devices are used in conjunction with the device.

Figure 9

SPST switch (single pole, single throw switch)

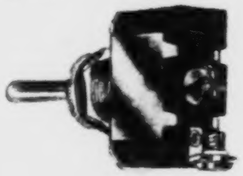
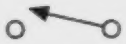
<table>
<tr><td>Control device:
</td><td>Wiring diagram symbol:

Used with permission of Ford Motor Co.</td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: connects and disconnects the circuit from the voltage</td></tr>
<tr><td colspan="2">One use: hazard lamp circuit</td></tr>
<tr><td colspan="2">How it works: The simplest type of switch, a SPST switch has one <i>wiper</i> that can move to connect the <i>contact</i> to the rest of the circuit. SPST switch contacts are either opened (off) or closed (on). A SPST switch can be manually operated or operated automatically under a specified condition such as temperature, pressure, voltage, or time delay.</td></tr>
</table>

Figure 10

SPDT switch (single pole, double throw switch)

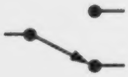
<table>
<tr><td>Control device:
 </td><td>Wiring diagram symbol:
</td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: determines which of two circuit branches is connected to the voltage.</td></tr>
<tr><td colspan="2">One use: cruise control switch</td></tr>
<tr><td colspan="2">How it works: A single-pole double-throw <i>SPDT switch</i> has a movable wiper that moves between two different contacts. Each contact is the beginning of a different branch of the circuit. A SPDT switch switches the voltage between these two branches. One of the two branches is always connected to the voltage; there is no <i>off</i> position for a SPDT switch. A SPDT switch can be manually operated, or operated automatically under a specified condition.</td></tr>
</table>

Figure 11

MPMT switch (multiple pole, multiple throw switch)

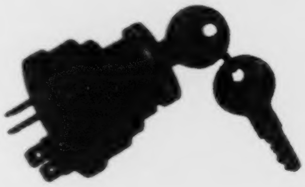
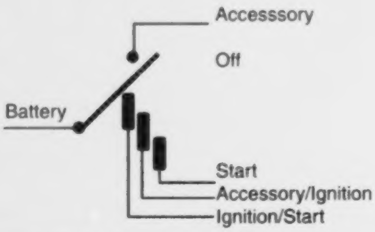
<table>
<tr><td>Control device:
</td><td>Wiring diagram symbol:
 </td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: determines which of several circuit branches is connected to the voltage</td></tr>
<tr><td colspan="2">One use: ignition switch</td></tr>
<tr><td colspan="2">How it works: Sometimes called a <i>ganged switch</i>, an <i>MPMT switch</i> has two or more wipers and two or more contacts It is the most complex of all switches. The wipers are connected to each other and always act together when moving over the contacts. Using an MPMT switch allows the selection of several alternate circuits that must always be connected at the same time.</td></tr>
</table>

Figure 12

pressure switch

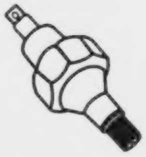
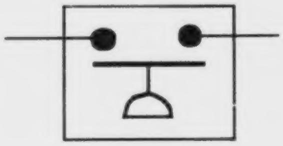
<table>
<tr><td>Control device:
</td><td>Wiring diagram symbol:
</td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: connects and disconnects the circuit from the voltage</td></tr>
<tr><td colspan="2">One use: oil pressure circuit switch</td></tr>
<tr><td colspan="2">How it works: A <i>pressure switch</i> connects or disconnects its circuit from the voltage when pressure on the switch changes. Most pressure switches have a diaphragm, which, under normal pressure, holds the contacts of the switch closed (or open). When the pressure is low, the diaphragm relaxes, opening (or closing) the contact. Pressure switches allow the monitoring of components or functions that depend on an accurate supply of pressure or vacuum.</td></tr>
</table>

Figure 13

mercury switch

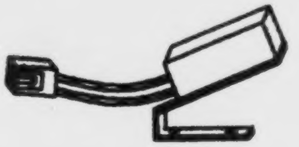
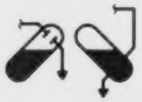
Control device: 	Wiring diagram symbol:  Used with permission of DaimlerChrysler Corp.
Current factor controlled: **voltage**	Type of control: **connects and disconnects the circuit from the voltage**
One use: **hood tilt switch**	
How it works: A *mercury switch* connects and disconnects its circuit from the voltage (or ground) when the position of the switch is changed. The switch contains a partially filled capsule of mercury with two electrical contacts located at one end. The switch is installed in a position so that when it is *off*, the liquid mercury rests in the part of the capsule that does not touch the electrical contacts. When the position of the switch is moved to its on position, the mercury flows to the other end of the capsule where it contacts both of the electrical contacts—completing the circuit and allowing current to flow.	
Warning: It is important to note that a liquid conductor such as mercury is useful in a switch like this, but mercury is an extremely poisonous element and the vapors from even a tiny amount of unenclosed mercury are harmful or fatal if inhaled. Handling mercury itself is, of course, even more dangerous. Do not examine or handle mercury that is not in a container. Report any spills or broken components containing mercury to your instructor.	

Figure 14

temperature switch

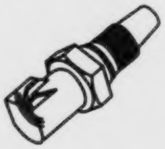
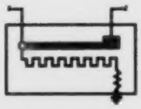
<table>
<tr><td>Control device:

Used with permission of Ford Motor Co.</td><td>Wiring diagram symbol:

Used with permission of DaimlerChrysler Corp.</td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: connects and disconnects the circuit from the voltage</td></tr>
<tr><td colspan="2">One use: engine temperature warning light circuit</td></tr>
<tr><td colspan="2">How it works: A <i>temperature switch</i> reacts to changes in temperature by connecting or disconnecting its circuit from the voltage. A typical temperature switch uses a bi-metal arm that reacts to heat. When heated, the arm warps or bends, opening or closing the circuit. As the arm cools, it resumes its original position, closing or opening the circuit.</td></tr>
</table>

Figure 15

relay

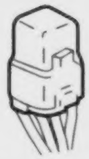
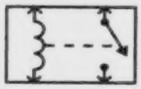
<table>
<tr><td>Control device:
</td><td>Wiring diagram symbol:

Used with permission of Ford Motor Co.</td></tr>
<tr><td>Current factor controlled: voltage</td><td>Type of control: connects and disconnects the circuit from the voltage</td></tr>
<tr><td colspan="2">One use: starter</td></tr>
<tr><td colspan="2">How it works: A <i>relay</i> uses current to create a magnetic field that draws the contact points together to connect the circuit to the voltage. Using a relay allows you to control a high-voltage and/or a high current circuit by remote control using a low-voltage, low-current relay circuit.</td></tr>
</table>

Figure 16

flasher

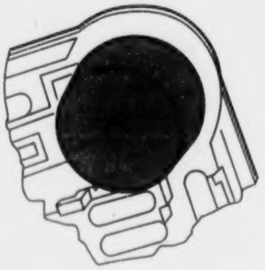
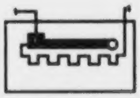
Control device: 	Wiring diagram symbol: 
Current factor controlled: **voltage**	Type of control: **connects and disconnects the circuit from the voltage**
One use: **turn signal circuit**	
How it works: A *flasher* works using a bi-metal strip and a small heating element. When current flows through the heating element, it warms and warps the bi-metal strip, briefly disconnecting the circuit from the voltage. The strip quickly cools and again touches its contact point, reconnecting the circuit to the voltage. This cycle is repeated on a regular basis, causing the lamp on the circuit to turn on and off in a flashing signal.	

Figure 17

capacitor

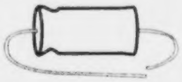
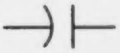
Control device: 	Wiring diagram symbol: 
Current factor controlled: **voltage**	Type of control: **stores and releases voltage**
One use: **ignition circuit**	
How it works: A *capacitor*, sometimes referred to as a *condenser*, controls the voltage in a circuit by storing it under some conditions and releasing it under others.	

Figure 18

fixed resistor

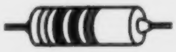
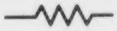
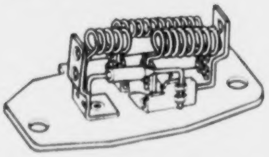
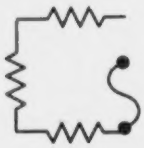
Control device:  Used with permission of DaimlerChrysler Corp.	Wiring diagram symbol: 
Current factor controlled: **resistance**	Type of control: **increases resistance in the circuit**
One use: **circuits using electronic components**	
How it works: *Fixed resistors* are made of materials with a high amount of resistance. When a resistor is placed in a circuit, the additional resistance causes the current in the circuit to decrease. Since resistors have preset resistance values, you can precisely adjust the amount of current in a circuit by adding one or more resistors. Sometimes fixed resistors are simply called resistors, but it is important to notice they are different from variable resistors.	

Figure 19

stepped resistor

Control device:  Used with permission of Ford Motor Co.	Wiring diagram symbol: 
Current factor controlled: **resistance**	Type of control: **increases or decreases resistance in the circuit**
One use: **heater blower motor circuit**	
How it works: A *stepped resistor*, sometimes called a *tapped* resistor, is a type of variable resistor that consists of a single resistor with two or more set contact points on the resistor. When the wiper on the switch is moved to one of these contacts, the circuit is completed. If the switch is moved to a contact that leaves a large amount of the resistor on the circuit, the circuit will conduct a smaller amount of current. If the switch is moved to a contact that leaves a small amount of resistor on the circuit, the circuit will conduct a larger amount of current. Stepped resistors are frequently used on motor circuits where several speeds are desirable.	

Information Sheet

Figure 20

rheostat

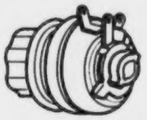
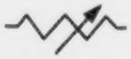
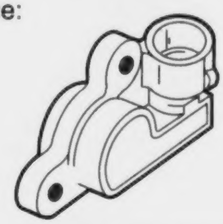
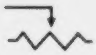
Control device:  Used with permission of DaimlerChrysler Corp.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Current factor controlled: **resistance**	Type of control: **increases or decreases resistance in the circuit**
One use: **instrument panel light circuit**	
How it works: A *rheostat* is a variable resistor that has a wiper that can contact a fixed resistor at any point along its length. By turning or sliding a knob, the wiper will adjust the amount of resistance, thereby altering the amount of current, in a circuit.	

Figure 21

potentiometer

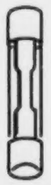
Control device:  Copyright © General Motors Corp. Used with permission.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Current factor controlled: **resistance**	Type of control: **increases or decreases resistance in the circuit**
One use: **throttle position circuit**	
How it works: A potentiometer is a variable resistor that works very much like a rheostat except that the circuit branches at the wiper. One branch of the circuit continues to the load while the other branch goes to a computer that monitors the current at the potentiometer. The addition of this second wire to the computer allows the potentiometer to act as a sensor to monitor the current in the circuit.	

Objective 8 Common protection devices, their illustrations and wiring diagram symbols

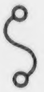
Figure 22

glass fuse

Protection device:



Wiring diagram symbol:



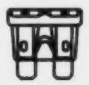
One use: **aftermarket accessory circuit**

How it works: A *glass fuse* is a small glass cylinder with a metal strip inside connected to metal terminals on each end of the cylinder. If a circuit is conducting an acceptable amount of current, the metal strip acts as a conductor and the circuit works normally. However, if there is too much current in the circuit, the strip overheats and melts, disconnecting the circuit from the voltage and protecting the other devices on the circuit from damage. This is called blowing a fuse. All protection devices, including fuses, are designed so that when the current is too high for the devices on the circuit, the protection device will disconnect the circuit from the voltage. Glass fuses, sometimes called *cartridge* or *bullet* fuses, have been replaced by blade fuses on most vehicles.

Figure 23

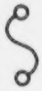
blade fuse

Protection device:



Used with permission of DaimlerChrysler Corp.

Wiring diagram symbol:



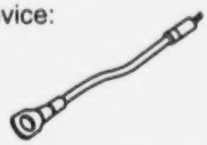
One use: **hazard warning lights circuit**

How it works: A *blade fuse* works the same way as a glass fuse; however, blade fuses are more compact and easier to remove and reinstall than glass fuses. Blade fuses also come in different sizes: *minifuse*, *autofuse* or *standard blade fuse*, and *maxifuse*. The blade fuse is the most commonly used vehicle fuse.

Figure 24

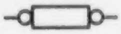
fusible link

Protection device:



Copyright © General Motors Corp. Used with permission.

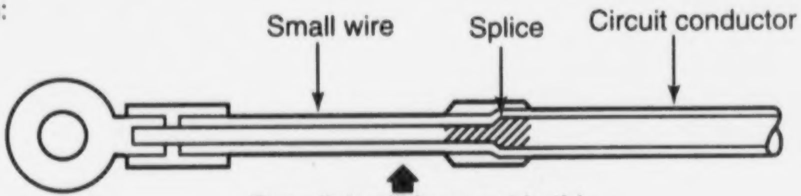
Wiring diagram symbol:



Used with permission of Ford Motor Co.

One use: **starter motor circuit**

How it works:



Fuse link will burn out in this area when too much current flows through.

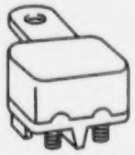
Used with permission of DaimlerChrysler Corp.

A *fusible link* is a short section of insulated wire usually installed close to the power source. A fusible link is frequently used to protect major power lines before they branch into separate circuits before the fuse box. Because a fusible link is slightly thinner than the wire in the circuit it protects, excess current causes the smaller wire in the fusible link to melt, disconnecting the circuit from the voltage. Fuses and fusible links are very similar. Like fuses, fusible links must be replaced after they are blown.

Figure 25

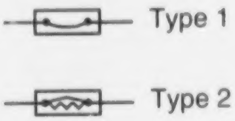
circuit breaker

Protection device: Type 1 or Type 2



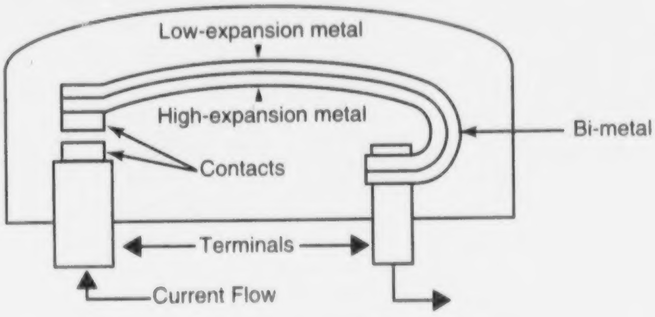
Used with permission of DaimlerChrysler Corp.

Wiring diagram symbol:



One use: **power window circuit**

How it works:



Used with permission of DaimlerChrysler Corp.

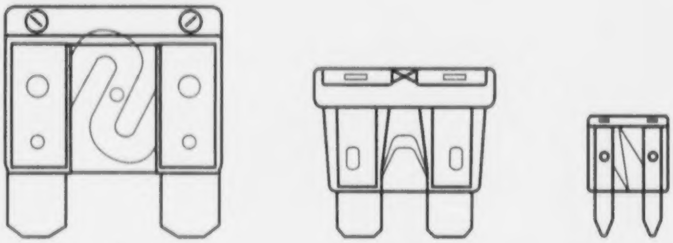
Like a fuse or fusible link, a *circuit breaker* also disconnects the circuit from the voltage when current becomes too high, but unlike these, it does not have to be replaced. A circuit breaker contains a bi-metal strip that, under an acceptable level of current, remains cool and straight. However, when too much current flows through the bi-metal strip, the strip becomes heated. Because the two types of metal in the strip expand at different rates when they are heated, the strip bends—opening the contacts on the breaker and disconnecting, or *tripping*, the circuit. When the strip cools, it returns to its normal state and again connects the circuit to the voltage. Some circuit breakers reset themselves automatically (Type 1), some will only reset automatically after power to the circuit breaker has been shut off (Type 2), and others must be manually reset by pushing a button on the circuit breaker (Type 3).

Objective 9

Size categories of blade fuses

Figure 26

Note: Blade fuses are the most common type of protection devices.



Maxifuse **Autofuse** **Minifuse**

a. Maxifuse

Note: Maxifuses can protect from 10-15 circuits at a time. Maxifuses are increasing in popularity and are taking the place of fusible links in many vehicles.

b. Autofuse or standard fuse

Note: Autofuses usually protect from 1-5 circuits each.

c. Minifuse

Note: Minifuses usually protect only 1-2 circuits. These are the size of blade fuses commonly found in vehicle fuse boxes.

Objective 10

How fuses, fusible links, and circuit breakers protect the circuits on which they are installed

Every fuse, fusible link, and circuit breaker is designed to conduct only a predetermined amount of current. When too much current flows through them, they melt, (or in the case of a circuit breaker, warp), disconnecting the circuit from the voltage before other circuit devices on the circuit can be damaged.

Objective 11

Common loads, their illustrations, wiring diagram symbols, and the form of energy into which each converts current

Note: *Loads* perform the work of the circuit—they're the reason the circuit exists. Power sources, control devices, protection devices, conductors, and grounds all exist to get exactly the amount of current to the load(s) at exactly the right time. Then the loads take over—transferring the current into the energy needed for the vehicle. This energy can take many forms—motion from the motors, light from the lamps, heat from the heated window grid, sound from the buzzers, spark from the spark plugs, and so on. Loads can be very simple, with no moving parts (like a cigar lighter) or very complex, containing many moving parts (like a generator). Remember that the loads listed here are common loads, not all the loads that are used in a vehicle.

Figure 27

lamp

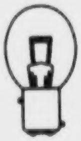
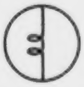
Load:	Wiring diagram symbol:
 Used with permission of DaimlerChrysler Corp.	 Used with permission of Ford Motor Co.
Form of energy: **light**	
One use: **headlamp circuit**	
How it works: A *lamp* contains a small wire called a filament in an airtight glass enclosure. The filament, which has a high resistance, heats up when it conducts current, giving off a bright glow or light.	

Figure 28

motor

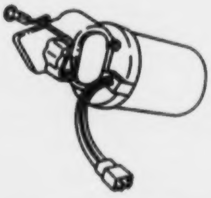
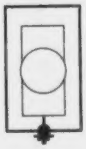
Load:	Wiring diagram symbol:
 Used with permission of Ford Motor Co.	 Used with permission of Ford Motor Co.
Form of energy: **motion**	
One use: **wiper motor circuit**	
How it works: A *motor* creates motion from current, using electromagnetic fields.	

Figure 29

gauge

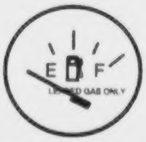
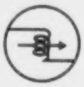
Load:  Used with permission of Ford Motor Co.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Form of energy: **motion**	
One use: **fuel gauge circuit**	
How it works: There are two basic types of *gauges.* In a *bi-metal gauge*, heat is used to bend the bi-metal strip which moves the pointer across the face of the gauge. A *magnetic gauge* uses a small coil to create a magnetic field that moves the gauge pointer.	

Figure 30

buzzer

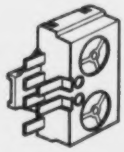
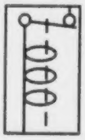
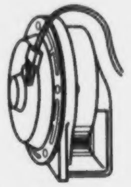
Load:  Used with permission of Ford Motor Co.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Form of energy: **sound**	
One use: **seat belt warning signal circuit**	
How it works: A *buzzer* is a load that makes an alarm sound. It works very much like a relay, but instead of closing a contact and starting voltage to a load, a buzzer opens a contact and stops the voltage to a load—itself. When a buzzer is supplied with current, it creates an electromagnetic field in a coil that pulls open a contact arm that stops the current to its own coil. This collapses the electromagnetic field, allowing the contact arm to close. Once closed, the current can again flow to the coil, again create the electromagnetic field, which again opens the contact arm—repeating the cycle. This rapid opening and closing of the buzzer contact creates the buzzing sound.	

Figure 31

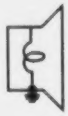
horn

Load:



Used with permission of Ford Motor Co.

Wiring diagram symbol:



Used with permission of Ford Motor Co.

Form of energy: **sound**

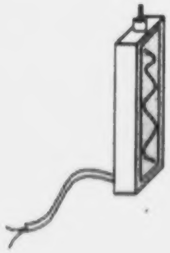
One use: **horn circuit**

How it works: Like a *buzzer*, a *horn* also produces sound using an electromagnetic field. However, the sound from a horn is considerably louder than a buzzer because in a horn the contact point that opens and closes is connected to a diaphragm. The rapid rising and falling of the diaphragm causes a column of air in the horn to vibrate, resulting in the louder sound. The shape of the horn and how rapidly the diaphragm vibrates determine the sound the horn makes.

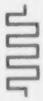
Figure 32

heated mirror

Load:



Wiring diagram symbol:



Form of energy: **heat**

One use: **heated mirror grid circuit**

How it works: In a *heated mirror grid*, sometimes called a *de-icer*, a metallic grid is baked onto the inside of the glass and is connected to the circuit by a terminal soldered to one end of the grid. Another terminal on the other end of the grid grounds the circuit. As current flows through the grid, the resistance in the metal in the grid causes it to heat, warming the mirror and evaporating the fog or melting the snow and ice.

Figure 33

cigar lighter

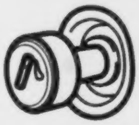
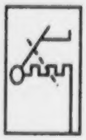
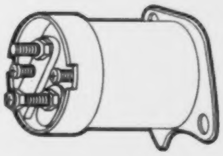
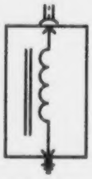
Load:  Used with permission of DaimlerChrysler Corp.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Form of energy: **heat**	
One use: **cigar lighter circuit**	
How it works: As current flows through the metal heating element in a *cigar lighter*, the high resistance in the metal creates enough heat in the element to light a cigar or cigarette.	

Figure 34

solenoid

Load:  Copyright © General Motors Corp. Used with permission.	Wiring diagram symbol:  Used with permission of Ford Motor Co.
Form of energy: **motion**	
One use: **door latch circuit**	
How it works: A *solenoid* is an electromagnetic device that uses electric current to move mechanical parts. When current flows into the coil in a solenoid, the coil magnetizes an iron core, pulling it like a plunger into the coil. The pull of this plunger engages other mechanical parts. What those other parts are depends on how the solenoid is used.	

Objective 12

How a device that is electronic is different from a device that is electric

If current flows through a conductor in the device, the device is *electric*. If current flows through a vacuum, a gas, or a semiconductor in the device, the device is *electronic*.

Examples: Lamps, fuses, and resistors are electric; diodes, transistors, and computers are electronic.

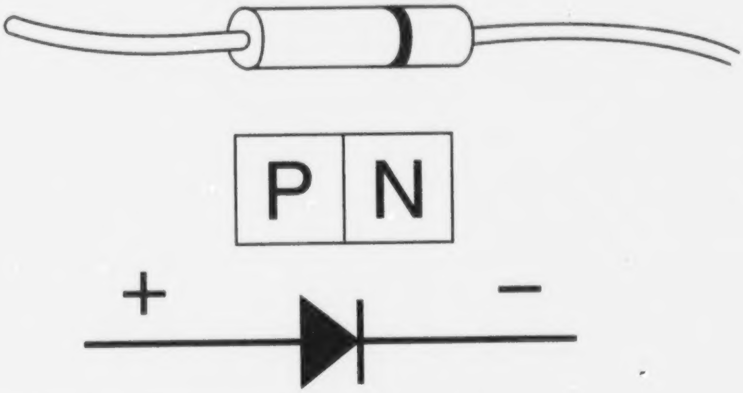
Note: Modern electronic devices are usually made using semiconductors.

Objective 13

P-type semiconductors and N-type semiconductors

Note: Depending upon what element is added during the doping, a semiconductor can be made to act as though it has either a positive charge or a negative charge. Current can be precisely controlled by doping the material through which you want it to flow. A heavily doped semiconductor can more easily conduct current than one that is lightly doped. All semiconductors used in electronics have been doped to influence their ability to conduct current.

Figure 35



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P-type semiconductor—A doped semiconductor that acts as though it has a positive charge—it attracts electrons.

N-type semiconductor—A doped semiconductor that acts as though it has a negative charge—it loses electrons.

Objective 14

Advantages and disadvantages of using electronic devices as circuits

a. Advantages

- More reliable

  Note: Because electronic devices have no moving parts, there is less chance for them to fail.

- Require no maintenance

  Note: Again, because electronic devices have no moving parts, they require no maintenance; if they do not function, they are discarded and replaced.

- Lighter
- Cheaper
- Operate using lower voltage

  Note: Because electronic devices conduct very small amounts of current, they operate with much less heat, and the magnetic field surrounding electronic conductors and circuit devices are very tiny. These advantages make the next two advantages possible.

- Smaller
- Function easily with computers

b. Disadvantages

- Can be easily damaged by too much current or by electrostatic discharge

  Note: Because electrostatic discharge is always present when working with electrostatic components, a technician should always take appropriate steps to protect such components during servicing.

- Are easily influenced by the magnetic field surrounding nearby conductors

Objective 15 **Common electronic circuit devices, their illustrations, wiring diagram symbols, and functions in a circuit**

Figure 36

diode

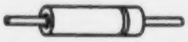
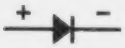
Electronic circuit device:  Copyright © General Motors Corp. Used with permission	Wiring diagram symbol:  Copyright © General Motors Corp. Used with permission
Function in a circuit: **control device**	
One use: **generator**	
How it works: The simplest kind of semiconductor, a *diode* is a two-layered electronic device that allows current to flow through it in only one direction. Used as a control device, it can either conduct current through the circuit or keep the circuit from conducting current, depending on how it is connected to the power source.	

Figure 37

zener diode

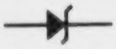
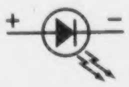
<table>
<tr><td>Electronic circuit device:
 </td><td>Wiring diagram symbol:

Copyright © General Motors Corp. Used with permission</td></tr>
<tr><td colspan="2">Function in a circuit: **control device**</td></tr>
<tr><td colspan="2">One use: **alternator**</td></tr>
<tr><td colspan="2">How it works: A *zener diode* is a special kind of diode which acts like a normal diode in that it conducts current normally when forward biased and blocks current when reverse biased. However, unlike a normal diode, when the reverse bias voltage reaches a certain level (called the zener voltage), a zener diode will conduct reverse current without being damaged. This unique quality is valuable, allowing zener diodes to regulate voltage in sensitive electronic circuits.</td></tr>
</table>

Figure 38

light-emitting diode (LED)

<table>
<tr><td>Electronic circuit device:

Copyright © General Motors Corp. Used with permission.</td><td>Wiring diagram symbol:


Copyright © General Motors Corp. Used with permission.</td></tr>
<tr><td colspan="2">Function in a circuit: **load**</td></tr>
<tr><td colspan="2">One use: **system warning lights**</td></tr>
<tr><td colspan="2">How it works: A *light-emitting diode*, or *LED*, has a small lens as part of its construction. This lens enables you to see light when current is flowing through the LED. Unlike a lamp, this light is not a result of heating a filament, but is actually visible electrical energy.</td></tr>
</table>

Figure 39

diode rectifier bridge

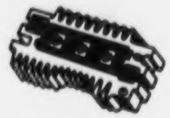
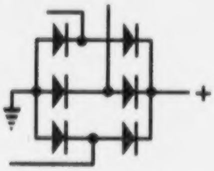
Electronic circuit device:  Copyright © General Motors Corp. Used with permission.	Wiring diagram symbol:  Copyright © General Motors Corp. Used with permission
Function in a circuit: **control device**	
One use: **alternator**	
How it works: A *diode rectifier bridge* uses diodes to change AC current into DC current that can be used by a vehicle's electrical system and stored in the battery.	

Figure 40

transistor

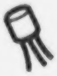
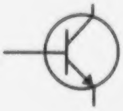
Electronic circuit device:  Copyright © General Motors Corp. Used with permission.	Wiring diagram symbol:  Copyright © General Motors Corp. Used with permission
Function in a circuit: **control device**	
One use: **horn circuit**	
How it works: *Transistors* are three-layered semiconductors that are used as very precise, rapid-action switches.	

Figure 41

phototransistor

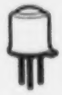
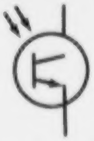
<table>
<tr><td>Electronic circuit device:

Copyright © General Motors Corp. Used with permission</td><td>Wiring diagram symbol:

Copyright © General Motors Corp. Used with permission</td></tr>
<tr><td colspan="2">Function in a circuit: control device</td></tr>
<tr><td colspan="2">One use: headlamp automatic dimming circuit</td></tr>
<tr><td colspan="2">How it works: Like a light-emitting diode, a <i>phototransistor</i> has a small lens as part of its construction. But where an LED gives off light, a phototransistor's lens focuses light onto the transistor, increasing the amount of current the transistor will conduct; the stronger the light, the more current will be conducted.</td></tr>
</table>

Figure 42

thermistor

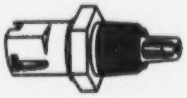
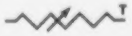
<table>
<tr><td>Electronic circuit device:

Used with permission of Ford Motor Co.</td><td>Wiring diagram symbol:

Used with permission of Ford Motor Co.</td></tr>
<tr><td colspan="2">Function in a circuit: control device</td></tr>
<tr><td colspan="2">One use: air charge temperature sensor</td></tr>
<tr><td colspan="2">How it works: A <i>thermistor</i> is a semiconductor device whose resistance value changes in relation to temperature. A thermistor is made of a plastic compound doped with carbon particles. When the thermistor is heated, the carbon in the plastic responds, loosening the molecular bonds in the material. This change turns the plastic into a conductor that allows current to pass.</td></tr>
</table>

Figure 43

darlington pair

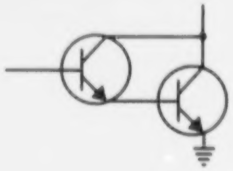
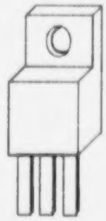
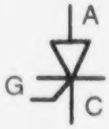
Electronic circuit device: (found only on circuit boards)	Wiring diagram symbol:  Copyright © General Motors Corp. Used with permission.
Function in a circuit: **control device**	
One use: **electronic ignition circuits**	
How it works: A d*arlington pair* consists of two transistors connected together. The first transistor is used to increase (or *amplify*) the current to operate the second transistor. The second transistor then amplifies the current even more until it is sufficient to operate a control or load later in the circuit. Darlington pairs are used to increase current from control modules for many switching applications.	

Figure 44

thyristor

Electronic circuit device: 	Wiring diagram symbol: 
Function in a circuit: **control device**	
One use: **control module outputs**	
How it works: Thyristors are bi-directional semiconductor devices with three terminals. This device can be switched back-and-forth between a high-current "on" state, and a low-current "off" state by applying a small current of either polarity between the gate and one of the two main terminals. Thyristors are solid-state switches that do not amplify fluctuating signls as transistors do. There are two types of thyristors; Silicon-Controlled Rectifiers (SCRs) and Triacs.	

6-0

Objective 16 | Common conductors, their illustrations and wiring diagram symbols

Figure 45

wire

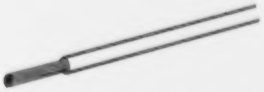
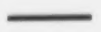
Conductor:  Copyright © General Motors Corp. Used with permission	Wiring diagram symbol: 
Note: A *wire* is the most common device that provides a pathway for current to move from one place to another. Wire is made of different materials in different sizes to accommodate current of different strengths and is commonly covered by plastic or rubber insulation.	

Figure 46

terminal

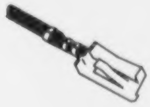
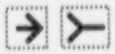
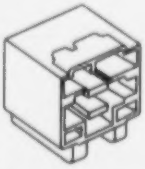
Conductor:  Copyright © General Motors Corp. Used with permission.	Wiring diagram symbol: 
Note: *Terminals* are devices that are crimped or soldered to a wire or other conductor to allow it to connect to another wire or conductor.	

Figure 47

connector

Conductor:



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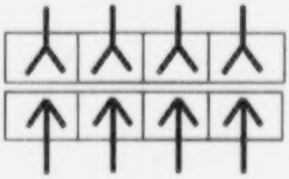
Wiring diagram symbol:

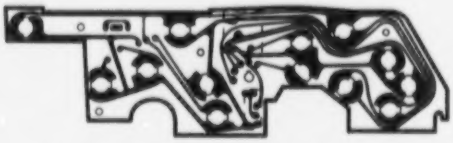


Note: *Connectors* are plastic and metal cases inside which two terminals are joined. To simplify the wiring, a single connector will often join several different pairs of terminals. Connectors hold the paired terminals firmly in place, making sure the terminals stay in contact despite the normal vibration of the vehicle.

Figure 48

printed circuit board

Conductor:



Used with permission of DaimlerChrysler Corp.

Wiring diagram symbol:

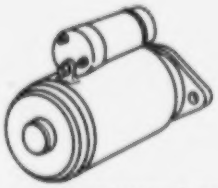
None

Note: A *printed circuit board* is a sheet of fiberglass or similar material printed with very fine lines of copper or other conductor material. These conducting lines on the circuit board take the place of wires, providing pathways for current to gauges, lights, indicators, and other loads which are located very close to each other. A printed circuit board is almost always used for instrument panel components.

Figure 49

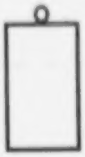
component case

Conductor:



Used with permission of DaimlerChrysler Corp.

Wiring diagram symbol:



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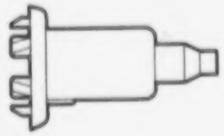
Note: Sometimes current is conducted through the *component case* that houses a circuit device. When this happens, the component case is usually screwed to the vehicle body or frame and the current flows through the case to the body and/or frame as it returns to the ground at the negative terminal of the battery.

Figure 50

socket

Conductor:



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Wiring diagram symbol:

None

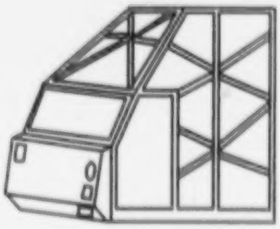
Note: *Sockets* are the plastic or metal housings into which light bulbs are mounted. Sockets are not merely a mounting component for the bulb. They are actually part of the circuit, making the connection between the wire or connector and the bulb.

Note: *These last three conductors conduct current from the last load or control device on the circuit back to the negative terminal of the battery where the circuit is grounded.* Except for component cases, wiring diagrams do not usually show that these three conductors are forming a pathway for the current back to the battery ground, but it is important that you realize that they are part of the circuit. If any of these parts are damaged or loose, they can interrupt current flow as surely as if the circuit were disconnected at any point that *is* shown on a wiring diagram.

Information Sheet

Figure 51

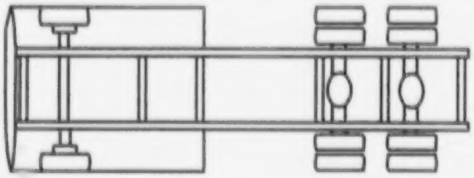
vehicle body

Conductor: 	Wiring diagram symbol: None

Note: The majority of vehicles today have a unitized metal *body* that provides a one-piece structure that holds the many parts that make up a vehicle. After a circuit has delivered current to its load(s), the circuit is connected to this metal body by a terminal and a screw. The current then flows through the vehicle body back to the battery where another wire (called a *ground wire*) screwed into the body connects the body to the negative terminal of the battery. All electric circuits in the vehicle use the body as the final pathway to the battery ground. You can imagine current flowing into the body from many different circuits. Once in the body, the current looks for a path that will take it away from the electromotive force of the power source. The wire connecting the body to the negative battery terminal provides this path. (See Unit 1, Student Supplement 2, "How Electricity is Created.")

Figure 52

vehicle frame

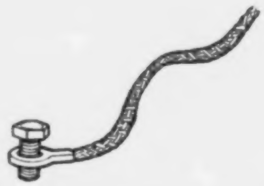
Conductor: 	Wiring diagram symbol: None

Note: Vehicles that do not have a unitized body have a *frame* to which vehicle body parts such as the fenders, suspension, and engine are attached. Even vehicles with a unitized body have a *subframe* under the engine to provide additional support to this heavy component. Sometimes electrical circuits are screwed to the vehicle frame (or subframe). The frame will receive current from any circuits screwed to it, and then will conduct the current through the frame to a *ground strap* that attaches the frame to the vehicle body (or body part). Then the body conducts the current back to the negative terminal of the battery through the *ground wire*.

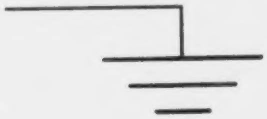
Figure 53

ground strap/wire

Conductor:



Wiring diagram symbol:



Note: A *ground strap*, made of braided wire, conducts current from the vehicle frame to the vehicle body; a *ground wire* conducts current from the vehicle body to the negative terminal of the battery.

Objective 17

Four types of material that are commonly used as insulators in vehicle electrical systems

Note: Controlling the path of the current is not only important as a safety feature to keep you from getting a dangerous electrical shock, but it is also very important to the functioning of the electrical system as a whole. If conductors and other circuit devices were not insulated, the current could travel through all conductive materials that touched anything on the circuit. Organized use of the current to achieve specific purposes at specified times would be impossible.

a. **Rubber**

Example: wiring jackets (especially for wires conducting high-voltage current)

b. **Plastic**

Example: connectors, wiring jackets

c. **Porcelain**

Example: sensors

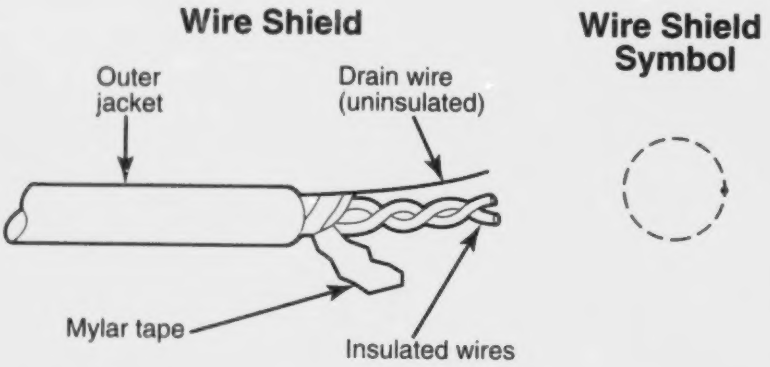
d. **Paper**

Example: capacitors, alternator stators

Objective 18

Purpose of a wire shield

Figure 54



A *wire shield* protects a wire from the influence of the electromagnetic energy which surrounds nearby electrical circuits so the energy does not interfere with the operation of circuits serving electronic components or components to radio or sound equipment.

Note: *Wire shields* are tubes of flexible wire mesh or jackets of braided wire that are installed around wires leading to sound equipment (radios, speakers, etc.) and certain electronic components. A layer of insulation is placed between the wire shield and the wire being shielded. Without a wire shield, operation of sound components would be disturbed by the normal electromagnetic energy from nearby wires, causing static noise in the sound from the radio, tape, or CD player. And without a wire shield, electromagnetic pulses from nearby wires would upset the tiny voltage signals used by electronic circuits. Wires fitted with wire shields are sometimes called *coaxial cables.*

Objective 19

Three purposes of wiring hardware

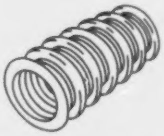
a. Part 1

- Support the electrical wiring
- Keep the wiring in the correct position
- Protect the wiring from being damaged

b. Part 2

Tubing

Figure 55



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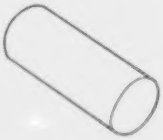
Sleeve

Figure 56



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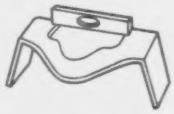
Retainer

Figure 57



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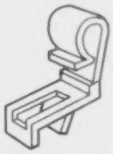
Clip

Figure 58



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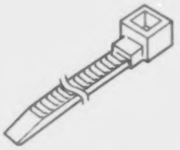
Tie strap

Figure 59



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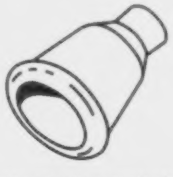
Boot

Figure 60



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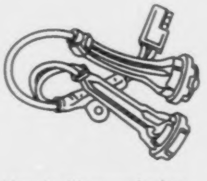
Wiring harness

Figure 61



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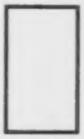
Note: A *wiring harness* is a bundle of several wires that are wrapped together or enclosed in flexible tubing. Wiring harnesses are used to protect and organize the many wires in a vehicle. As various wires are used for their circuits, they separate from the wiring harness and connect to the other devices necessary to their task. A *sleeve* is sometimes called a *shrink tube* as it is heated so it shrinks to fit firmly around the wires it protects.

Objective 20

Common circuit features and their wiring diagram symbols

Sealed or solid state component

Figure 62



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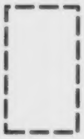
Component shown in two places

Figure 63



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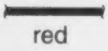
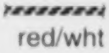
Solid colored wire

Figure 64



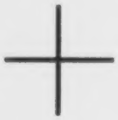
Striped wire or wire with a tracer

Figure 65



Wires crossed, not connected

Figure 66



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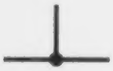
Splice

Figure 67



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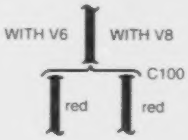
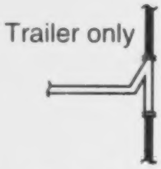
Alternate circuit path

Figure 68



Optional wiring

Figure 69



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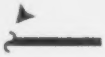
Wire continues somewhere else

Figure 70



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Objective 21

Types of wiring diagrams

Note: A wiring diagram is a drawing that shows the position circuit devices occupy in relation to each other. To simplify the drawing, symbols are used to represent circuit devices. Diagrams do not show the location of the devices in the vehicle, but there may be a side note stating where a specific component may be located. All drawings are drawn with power off unless otherwise noted on the drawing.

a. **Single line diagram**

- Allows tracing of each individual circuit
- Used for most troubleshooting procedures

b. **Harness diagram**

- Shows how the vehicle's harness is laid out
- Numbers on the harness body indicate how long that particular run of harness is
- Shows connector and terminal manufacturers as well as their part numbers
- Shows where each wire "breaks out" of the harness and where it connects into a terminal
- Not suitable for troubleshooting by itself

  Note: Harness drawings are not suitable for troubleshooting because wires that enter the harness may not exit because they are spliced within the harness.

c. **Ladder diagram**

- Each horizontal (ladder) rung is an individual basic circuit
- Diagram may be several pages long with circuit devices on different pages
- Can be difficult to use for troubleshooting

d. **Routing diagram**

- Shows how harness is routed through vehicle
- Shows connector locations on vehicle
- Shows grounding points on vehicle
- Shows component locations on vehicle
- Not suitable for troubleshooting by itself

Student Supplement 1—Capacitors

A ***capacitor***, sometimes called a *condenser*, controls the voltage in a circuit by storing it under some conditions and releasing it under others.

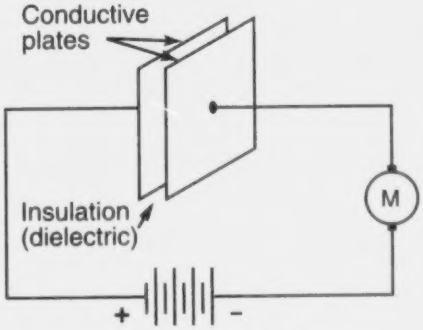
How a capacitor works

Capacitors work using a scientific principle you learned in Unit 1:

Unlike electrical charges attract each other.

A simple capacitor is made of two conductors separated by an insulator (Figure 1). Wires connect both conductors to the battery—one conductor to the positive terminal and the other conductor to the negative terminal. The two conductors never touch each other.

Figure 1



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When the capacitor is connected to a power source such as the battery, electrons from the negative terminal of the battery immediately collect on the conductor nearest the negative terminal while electrons from the conductor nearest the positive terminal are drawn away to the positive terminal of the battery (Figure 2). This quickly creates a difference in charge, called an *electrostatic field*, between the two conductors.

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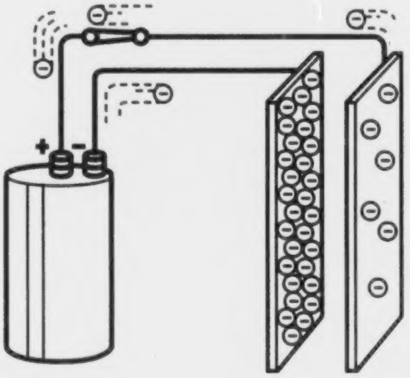
Figure 2



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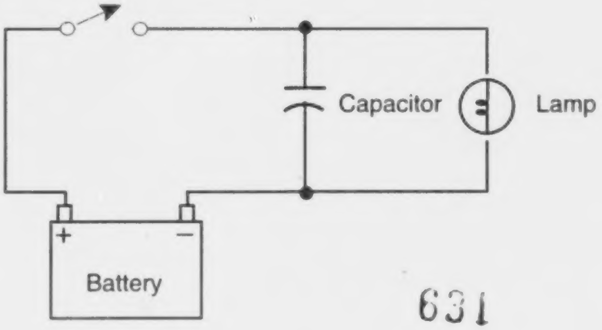
Current briefly flows in the circuit until the capacitor is *charged*—that is, until the voltage in the capacitor equals the voltage in the battery. Once the charge between the battery and the capacitor is balanced, no difference in charge exists in the circuit and current stops—to the capacitor and to any other device on its circuit. This ability of two conductive surfaces, separated by an insulator, to store an electrical charge (voltage) is called *capacitance*.

Uses in Vehicles

- **Voltage regulator**—If a capacitor is installed in a parallel or series-parallel circuit such as the one in Figure 3, the capacitor can be used to control voltage fluctuations in the entire circuit. Although, when charged, the capacitor in Figure 3 stops the current flow in the circuit branch on which it is installed, it does not stop the current to the branch on which the load is installed. If the battery voltage rises or falls from its normal level, the capacitor will instantly absorb or release the additional charge in an effort to maintain its balance in charge between its conductive plates and the battery. The capacitor's action protects circuit devices on parallel branch circuits from damage caused by voltage spikes.

Figure 3



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- **Blocking capacitor**—Because alternating (AC) current flows first one way then the other in a rapid pulsation, capacitors installed on circuits using AC current rapidly charge and discharge, in effect allowing current flow. Capacitors used on AC circuits such as those with sound equipment such as radios, speakers, or tape players, will filter out stray DC current that can cause static noise.

- **Timer mechanisms**—Since the amount of time it takes a specific capacitor to charge and discharge is constant and can be repeated again and again, capacitors can be installed in a circuit with resistors to construct timers.

- **Rapidly stop or start voltage**—Because capacitors instantly absorb and store any excess voltage in a circuit, they are sometimes used to quickly stop current. Capacitors are sometimes used this way in the ignition system. In other applications, such as in circuits for air bags, a capacitor's ability to instantly release voltage is used to deploy the air bags in the rapid response time necessary for their effective use.

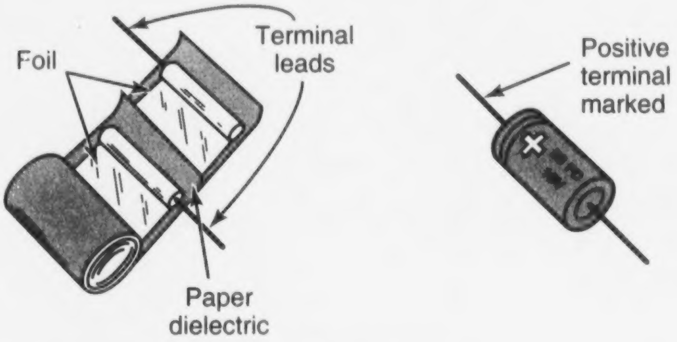
Although capacitors can store voltage like a battery can, they have limited use as a power source for two reasons. A capacitor cannot store as much voltage as a battery for its weight and size, and a capacitor's voltage decreases rapidly as soon as it is used.

Once charged, a capacitor can be removed from the circuit and still hold its charge. Although a capacitor is small, it can deliver a severe (even fatal) shock. To avoid shock, you should always handle capacitors as though they were charged until you can prove that they are discharged.

Capacitor construction

Capacitors come in a variety of shapes and sizes. In most cases, they are either flat, disc-shaped components, or they are tubular in shape. They vary in size from almost microscopic to the size of an AA battery, resembling fixed resistors without the color bands.

Figure 4



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Most vehicle capacitors are cylinders (Figure 4) made of two or more layers of metal foil alternating with layers of plastic or paper insulation. (In a capacitor, the insulating layer is called the dielectric.) Wires are attached to the separate layers of foil and a layer of paper or plastic insulation surrounds the cylinder. Disc-shaped capacitors are made of two metal discs separated by a ceramic dielectric.

Capacitor ratings

The capacitance of any capacitor is determined by:

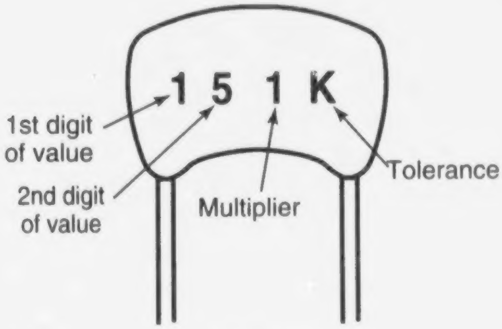
- the area of its conductive plates (the greater the area, the greater the capacitance),
- the distance between the conductive plates (the closer the plates, the greater the capacitance), and
- the material used as the dielectric (the better the insulators, the greater the capacitance and the capacitor's ability to hold a charge).

Temperature can also affect capacitance, but rarely does so.

Capacitors are rated in a unit of measurement called a **microfarad (μF)**, which specifies how many electrons the capacitor can store. Capacitors also have a **voltage rating** which indicates the maximum voltage the capacitor can handle without being damaged. When replacing a capacitor, you should always use a capacitor with the same or a larger voltage rating than the one you are replacing.

A capacitor's rating is usually printed on it, although some manufacturers may use a code (Figure 5). If a code is used, it is best to consult the manufacturer's service manual.

Figure 5



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Calculating total capacitance

The total capacitance of a circuit depends on what kind of a circuit the capacitors are in (Figure 6).

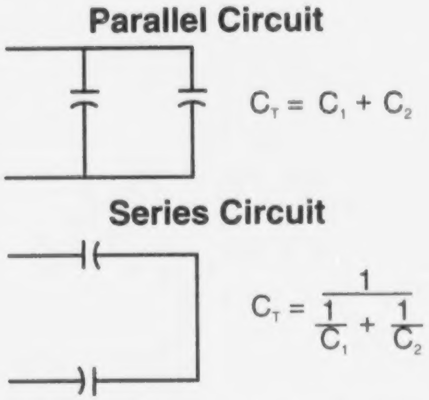
If the capacitors are in a parallel or a series-parallel circuit, use the following equation to calculate total capacitance:

$$C_T = C_1 + C_2 + C_3 \ldots$$

When the capacitors are in a series circuit, use the following equation to calculate total capacitance:

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$

Figure 6


Parallel Circuit
$C_T = C_1 + C_2$
Series Circuit
$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$

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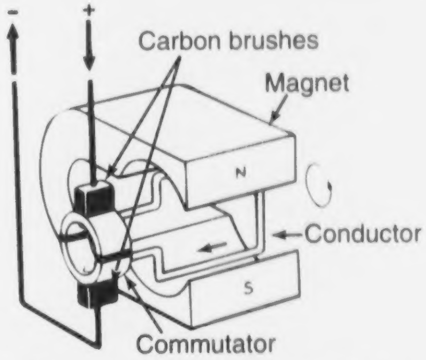
Student Supplement 2—Motors

Operating principles

A conductor carrying electric current creates a magnetic field surrounding it at a right angle to the conductor. When a looped conductor carrying current is placed inside a permanent magnet (Figure 1), the two magnetic fields interact. The magnetic field inside the permanent magnet combines with the magnetic field surrounding the conductor to attract the conductor on one side of the loop and repel it on the other side. This pushing-pulling force rotates the conductor.

The looped conductor is welded to a uniquely constructed metal ring called a commutator. The simple *commutator* shown in Figure 1 is made of a split ring bonded together with an insulator between the two metal halves. Two stationary brushes made of a copper and carbon compound are connected to the circuit—one brush connected to the negative terminal, the other to the positive terminal. As the conductor and the commutator rotate, these brushes brush against the commutator, maintaining a steady connection to the power source. In the resulting circuit (Figure 1), current flows from the power source through the top brush into the top half of the commutator. From there it flows into the conductive loop, through the bottom half of the commutator, into the bottom brush, and on to the ground.

Figure 1



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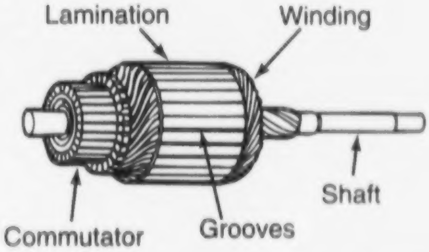
Motor construction

Like the simple motor above, all motors consist of a conductor interacting with a magnet, but engineers have modified the design to increase the power of the motor.

The *armature* is the movable part of the motor. The simple motor in Figure 1 has only one loop conducting current through the magnetic field. In an actual motor, many loops are used. In the armature (Figure 2), a conductor is wound around a core (or *lamination*) made of thin circular iron disks stacked over a steel shaft.

Figure 2



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The conductive loops called *windings* are made of copper ribbon or coils imbedded in long, deep grooves cut into the lamination parallel to the shaft. At their ends, the windings are soldered or welded to the numerous segments of the commutator. Like the simple commutator in Figure 1, these segments are insulated from each other, and half of the segments pick up current from one brush, conducting current to the windings; the other half of the segments transmit current from the windings to the other brush.

A steel *shaft* is inserted through the lamination and the commutator. This shaft is the part of the motor that transfers the motion of the turning armature to whatever mechanical components will use the motion. The shaft is insulated from the commutator and the core so that no electrical current is transferred to these other mechanical parts.

Although many motors, such as windshield wiper motors, use permanent magnets (Figure 3) as the stationary magnet that interacts with the armature, some more powerful motors, such as starter motors, may use an electromagnet called a *field coil*. You might think of the field coil as a powerful electromagnet with curved poles (Figure 4).

Figure 3

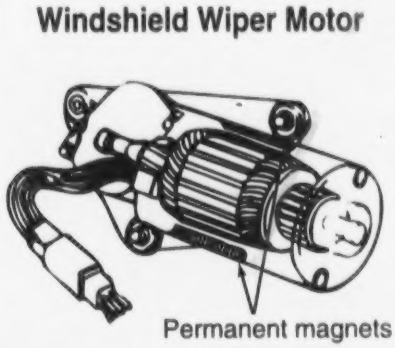

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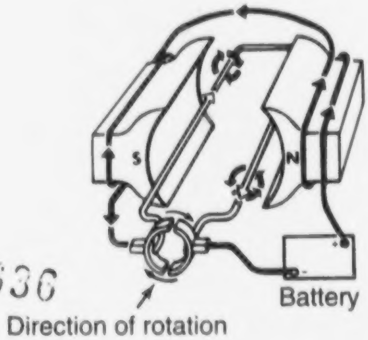
Figure 4



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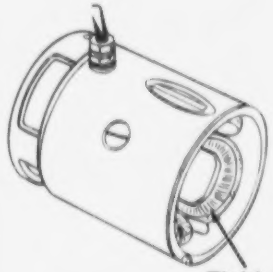
Field coils (Figure 5) are made of coils of wire or wire ribbon wound around an iron core called a *pole shoe*. The polarity (N-S) of an individual field coil depends on which direction the wire is wound around the pole shoe. Four pole shoes are installed alternating N-S-N-S around the inside of the motor field frame. The pole shoes are curved so that the armature can pass very close to the field coils as it rotates. This increases the power of the interaction between the electromagnets and the armature.

Figure 5



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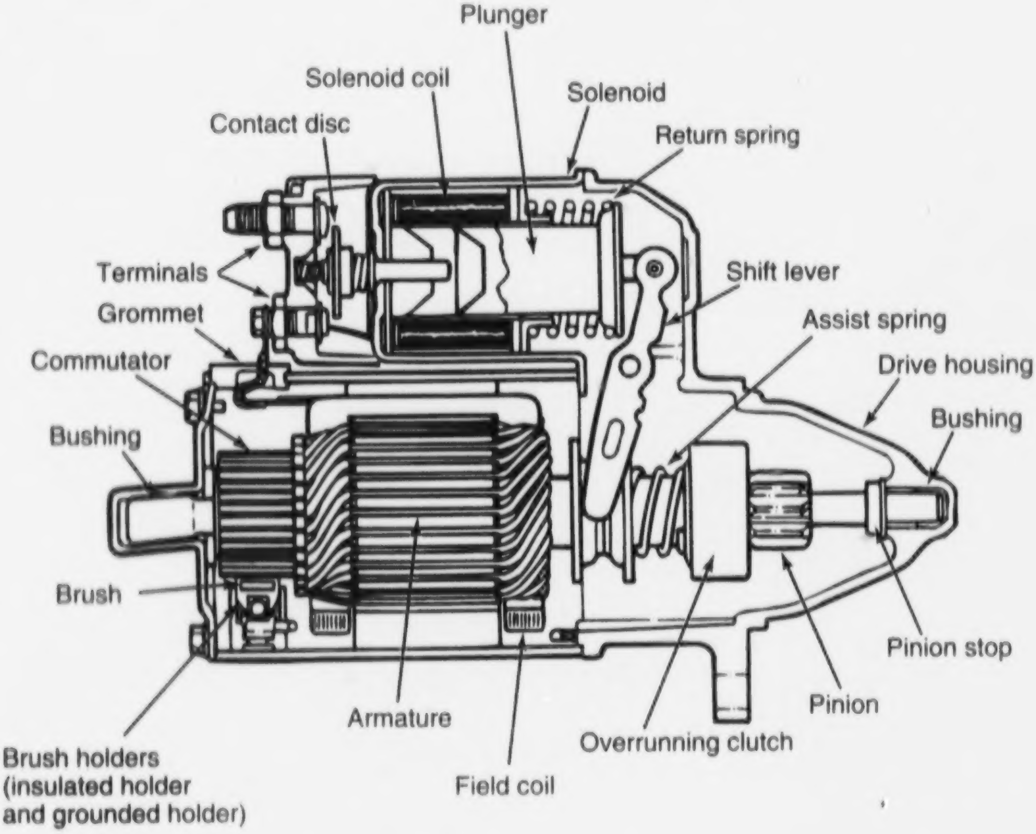
Although the designs of motors can vary widely depending upon the tasks they are expected to accomplish, the operating principles and basic construction of a motor are relatively the same. Figure 6 shows the design of a starter motor.

Figure 6


Plunger
Solenoid coil
Solenoid
Contact disc
Return spring
Terminals
Shift lever
Grommet
Assist spring
Commutator
Drive housing
Bushing
Bushing
Brush
Pinion stop
Pinion
Armature
Overrunning clutch
Brush holders
(insulated holder
and grounded holder)
Field coil

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Student Supplement 3—Diodes

A diode, made of a single P-type semiconductor joined to a single N-type semiconductor, is the simplest type of semiconductor device. In a circuit, diodes serve as check valves, allowing current to flow in only one direction.

Two Types of Semiconductors

Pure semiconductors don't conduct electricity well. The electrons in an atom of a pure semiconductor are bonded tightly by its nucleus; there's no place for the electrons to move. However, semiconductors can be made to conduct electricity by introducing a controlled number of atoms of another element into a pure semiconductor—a process referred to as ***doping***.

For example, a semiconductor such as silicon (with 4 valance electrons) might be doped with the element phosphorus, which has 5 electrons in its valence ring. A phosphorus atom can displace a silicon atom without disrupting the crystalline structure of the silicon, but the extra electron it brings has no place in the atomic bond between the two elements. Under normal circumstances, the extra electron remains in the vicinity of the phosphorus atom, but it can be made to move by applying a small voltage to the crystal. Doping silicon with phosphorous increases the number of free electrons in the doped semiconductor.

Silicon can also be doped with boron, an element whose atoms have 3 electrons in their valence ring. Each boron atom inserted in the silicon creates a *deficiency* of one electron, a state that is called an electron *hole*. An electron ***hole*** is not a real or physical particle, but merely a term indicating *the absence of an electron at a position where one would be present in a pure semiconductor*. Like the extra electrons in the phosphorus-silicon semiconductor, the electron holes in the boron-silicon semiconductor have no effect under normal circumstances. But like the electrons, the electron holes can be moved by applying a small voltage to the crystal. Doping silicon with boron *decreases* the number of free electrons in the resulting doped semiconductor.

A semiconductor doped with an element that causes the number of free electrons to *increase* is called an ***N-type semiconductor***. The "N" stands for *negative* electric charge, associated with an excess of electrons. An N-type semiconductor acts as though it has a negative charge—it loses electrons.

A semiconductor doped with an element that causes the number of free electrons to *decrease* is called a ***P-type semiconductor***. The "P" stands for *positive* electric charge, associated with the absence of an electron at a position where one would ordinarily be present. A P-type semiconductor acts as though it has a positive charge—it *gains* electrons.

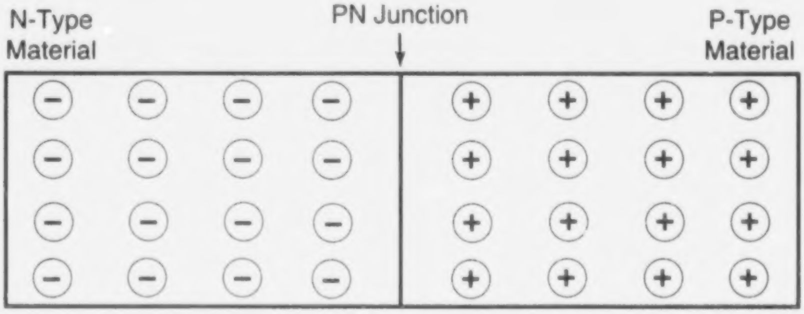
Normally, materials with such a low number of free electrons are not good conductors. However in semiconductor devices, current results not only from the movement of the electrons, but also by the movement of the *holes*.

Student Supplement 3

The PN Junction and Barrier Voltage

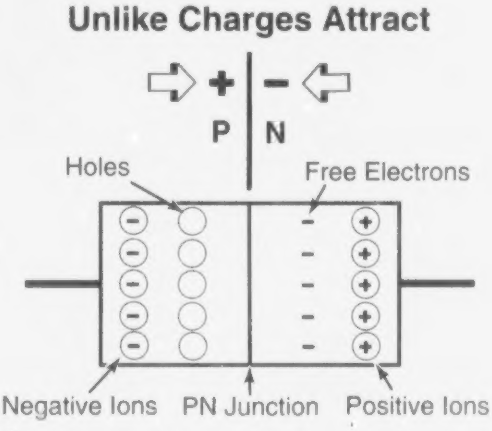
In semiconductor devices, N-type semiconductors and P-type semiconductors are layered adjacent to each other, and free electrons gather on one side (the N side) and holes gather on the other side (the P side). The point where the N-type semiconductor and the P-type semiconductor connect is called the ***PN junction*** (Figure 1).

Figure 1


N-Type Material
PN Junction
P-Type Material

At the PN junction, some of the free electrons in the N-type semiconductor fill the holes in the P-type semiconductor, and some of the holes in the P-type semiconductor move over to the N-type semiconductor (Figure 2). This happens only in a very small area called the depletion region. Inside the ***depletion region***, the movement of electrons and holes results in the P side gaining a small negative charge and the N side gaining a small positive charge. In the absence of any applied voltage, the balance of these charges prevents additional electrons and holes from crossing the junction.

Figure 2


Unlike Charges Attract
+
−
P
N
Holes
Free Electrons
Negative Ions
PN Junction
Positive Ions

6.0

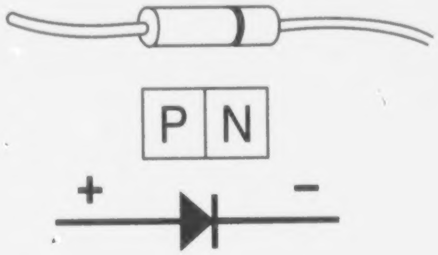
When you combine positive and negative charges in the depletion region, a small voltage potential results. This voltage potential across the PN junction is called the ***barrier voltage***. Doped germanium has a barrier voltage of about 0.3 volts; doped silicon has a barrier voltage of about 0.7 volts.

When voltage is applied to combined N-type and P-type semiconductors, electrons flow from the N-type semiconductor, across the PN junction, and through the P-type semiconductor. Electron holes flow in the opposite direction. The effect of the combined material on current flow in a circuit depends on (1) where it is placed and (2) the order of the P-type and the N-type semiconductors.

Diode Construction

A ***diode*** is the simplest kind of semiconductor device; it allows voltage to flow in one direction only. A diode is made of a single layer of P-type semiconductor and a single adjoining layer of N-type semiconductor. (Figure 3)

Figure 3



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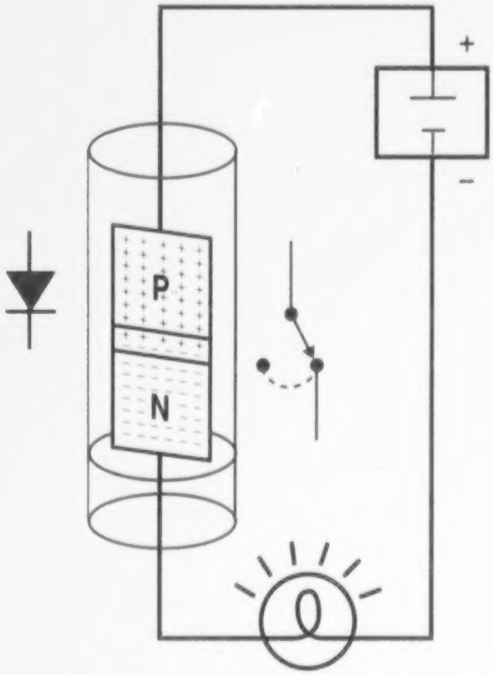
The positive side (P-type semiconductor) of the diode is called the ***anode*** and the negative side (N-type semiconductor) of the diode is called the ***cathode***. On a wiring diagram, the triangle in the diode symbol points in the direction current is permitted to flow. Actual diodes are two-lead devices with tubular bodies similar to fixed resistors. They have a single colored band close to one end.

Diodes allow current to flow in only one direction. A diode that is connected to the voltage so that the current *is* able to flow is called a ***forward biased*** diode. Notice that the diode in Figure 4 has its P side installed to the positive terminal of the battery and the N side connected to the negative terminal of the battery. If you remember that like charges repel each other and unlike charges attract each other, you can guess how the diode works.

Figure 4



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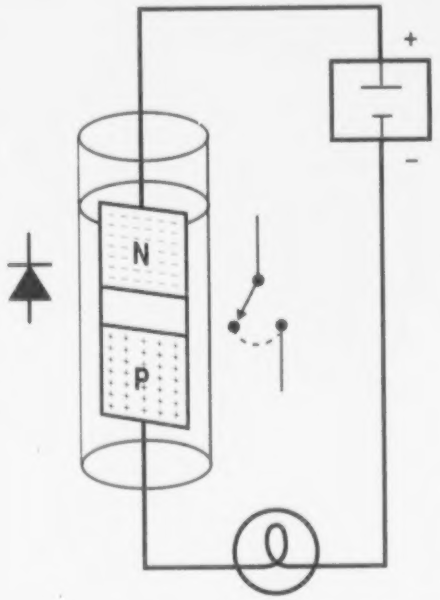
The holes in the P side of the diode are repelled by the positive terminal of the battery and attracted by the negative terminal of the battery. The free electrons in the N side of the diode are repelled by the negative terminal of the battery and attracted by the positive terminal of the battery. This means that both electrons and holes are being forced into the depletion zone, and current flows in the circuit.

A diode that is connected to the voltage so the current *is not* allowed to flow is called a reverse biased diode (Figure 5). A ***reverse biased*** diode is connected to the battery with the N side installed to the positive terminal of the battery and the P side connected to the negative side of the battery. Connected in this way, the electrons from the negative terminal combine with the electron holes in the P-type semiconductor. The electrons in the N-type material are attracted towards the positive terminal. The electrons and holes are drawn away from the PN junction, enlarging the depletion area. Since holes and electrons in the depletion area don't combine, current can't flow.

Figure 5



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Diode Leakage Current and Reverse Voltage

Actually, a tiny amount of current can flow through a reverse biased diode. If the voltage is high enough, the atomic bonds inside the diode will break apart and the amount of current will rise dramatically. If such current is large enough and lasts long enough, the diode will be damaged by the heat. The amount of voltage necessary to cause a diode to fail is called the *maximum reverse voltage*. (Maximum reverse voltage is sometimes called the *Zener point*, or *avalanche point*.) Diodes are rated according to their maximum reverse voltage.

Uses of Diodes in a Circuit

Voltage control—Although a normal diode will eventually be destroyed if its maximum reverse voltage is reached, a specially-constructed *Zener diode* will actually conduct current in reverse once its maximum reverse voltage level is reached. Zener diodes (Figure 6) are heavily doped semiconductors, resulting in a very high number of free electrons and electron holes. A Zener diode will conduct current normally in the forward-biased position, but once its maximum reverse voltage is reached, it will instantly begin conducting current the other direction. Zener diodes make excellent voltage regulators on a circuit and are often used to protect sensitive electronic circuits.

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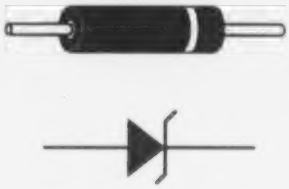
Figure 6



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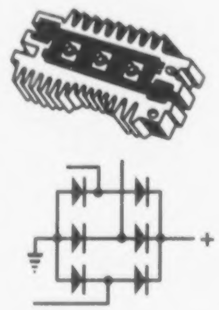
Protection from voltage spikes—When the current is shut off to the coil in an electromagnetic device (such as a relay or a solenoid), the magnetic field collapses, releasing all of the voltage at once in a large voltage *spike*. This sudden high voltage can damage semiconductor devices. To keep a collapsing electromagnetic field from creating a spike, a reverse biased diode is connected in parallel with the electromagnetic device. While current is flowing, the diode has no effect on the current. But when the current stops and the magnetic field collapses, the diode becomes forward biased and stops the current, clamping the voltage at a low value that will not damage the semiconductor devices. A diode used in this way is called a *clamping diode*.

Circuit control—In their simplest uses, combinations of diodes act as check valves, directing current in specific directions between circuits.

Rectification—A special arrangement of several diodes, called a *rectifier bridge* (Figure 7) is used to change or *rectify* alternating current (AC) into direct current (DC) in the vehicle's charging system. You will learn more about how this works in Unit 7.

Figure 7



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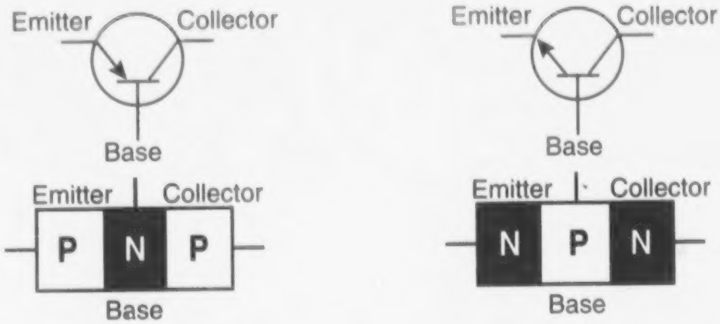
Student Supplement 4—Transistors

Transistors are semiconductor devices used to control current. The word ***transistor*** comes from two words: *trans(fer) + (res)istor*. Transistors change from conductors to resistors in response to electrical current. All transistors contain both N-type semiconductors and P-type semiconductors, but instead of two layers, transistors have three. (Figure 1) Transistors can have either:

- A single layer of N-type material sandwiched between two layers of P-type material (**PNP**), or they can have.
- A single layer of P-type material sandwiched between two layers of N-type material (**NPN**).

Instead of having two wires (or leads) like diodes, transistors have three—one from each layer. Look at the symbols for the transistors in Figure 1. The arrow indicates the direction of the current flow.

Figure 1



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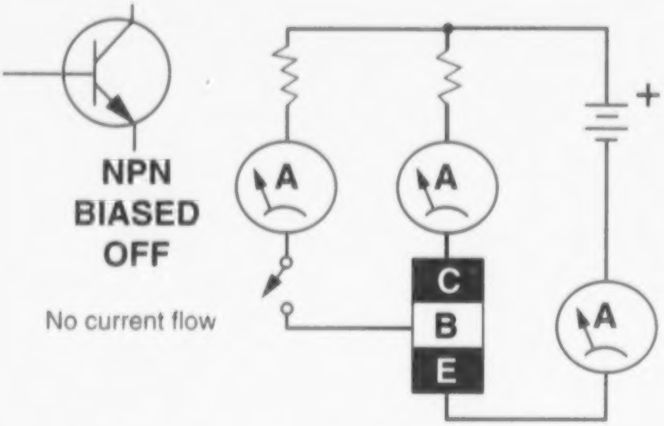
- If the transistor is a ***PNP transistor*** (on the left), the arrow in the symbol points *towards* the middle of the symbol.
- If the transistor is an ***NPN transistor*** (on the right), the arrow in the symbol points *away* from the middle of the symbol.

The middle layer of a transistor is called the *base*, the outer layer with the arrow indicating current flow is called the *emitter*, and the remaining outer layer is called the *collector*. The polarity of the collector and the emitter are always the same. The polarity of the base is always opposite that of the collector and emitter.

The current to the circuit's load(s) always flows through the emitter and the collector. But the current through the base of the transistor *controls* the current through the emitter and the collector. To illustrate this, look at Figure 2. In this figure, the rectangle CBE (collector, base, emitter) represents the transistor. When the switch on the branch circuit to the left is open, no current goes to the transistor's base (B) and therefore no current flows through the transistor or to any load beyond the transistor.

Figure 2


NPN
BIASED
OFF
No current flow
A
A
A
C
B
E
+

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However, when the switch is closed (Figure 3), current flows to the transistor's base (B), switching on the transistor and allowing current to flow through the transistor to any load in the circuit beyond the transistor. The small amount of current (.2 A) conducted in the branch controls the larger amount of current (4.8 A) in the middle branch and in the main circuit. This small current to the transistor's base is called the *base* (or *control*) *current*. By adjusting the tiny base current with a variable resistor (stepped resistor, rheostat, or a potentiometer), you can increase or decrease the large amount of current flowing into and through the transistor (Figure 4).

Figure 3

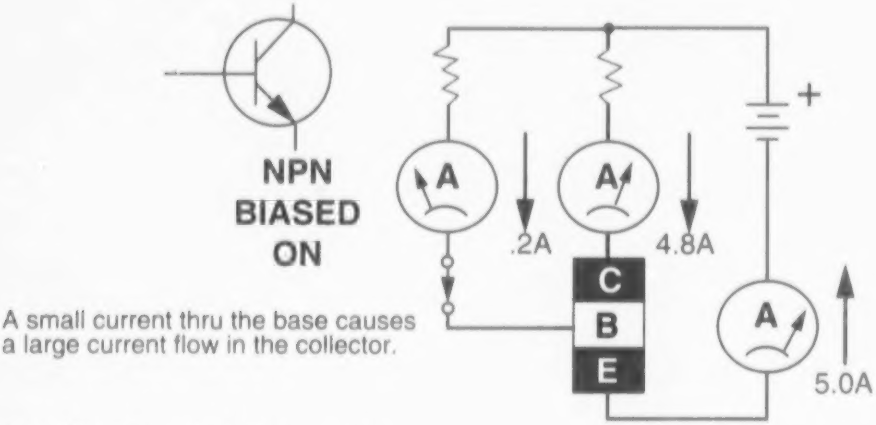
NPN
BIASED
ON
A small current thru the base causes
a large current flow in the collector.
A
A
A
.2A
4.8A
5.0A
C
B
E
+

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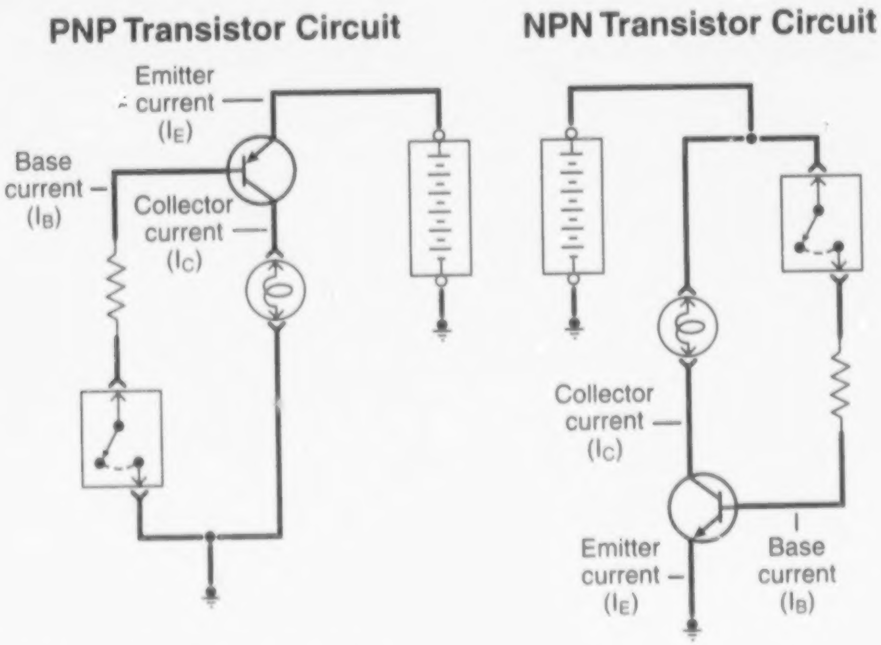
Figure 4


PNP Transistor Circuit
Emitter current (I_E)
Base current (I_B)
Collector current (I_C)
NPN Transistor Circuit
Collector current (I_C)
Emitter current (I_E)
Base current (I_B)

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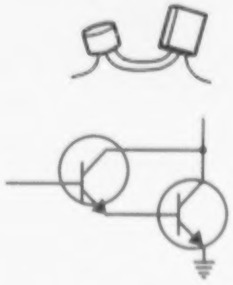
Keep two things in mind when you think about how a transistor works:

a. A transistor is turned on by applying voltage to the base and turned off by removing voltage to the base.

b. The current through the base (I_B) is always much smaller than the current through the collector circuit (I_C), and the current through the emitter circuit (I_E) is the largest of all. Changing the base current a little results in changing the collector current a lot and the emitter current the most. In fact, the base current plus the collector current will always equal the emitter current. For practice, label the base current (I_B), the collector current (I_C), and the emitter current (I_E) in Figure 3.

Figure 5



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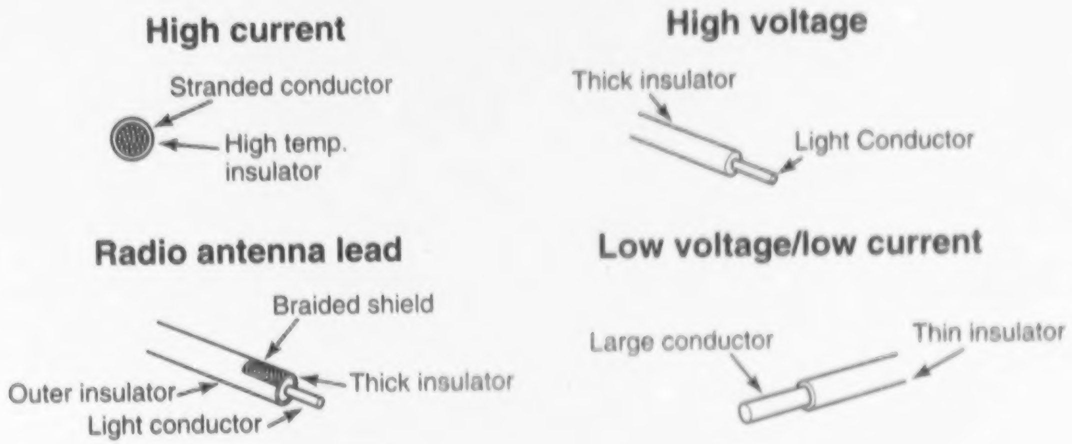
Sometimes the tiny amount of current used by an automotive computer when it monitors a function is too small to operate a load. In such instances, two transistors can be connected together (called a *Darlington pair*) and used to increase (or *amplify*) the current (Figure 5). The first transistor (called the *pre-amplifier*) uses its emitter current to feed a larger base current to the second transistor (called the *final amplifier*). This base current to the final amplifier yields an emitter current that is larger than would be possible if only one transistor were used. When transistors are used in this way, they are called *transistor amplifiers*.

In some circuits, transistors are used as switches that function much like *solid-state relays*. Transistors used in this way are faster, smaller, and won't wear out like ordinary relays. Like diodes, transistors are used in combination for specific applications.

Student Supplement 5—Electrical Wire

Conductors provide pathways for current to move between the other circuit elements. *Wire* is the main conductor in vehicle electrical systems. Each wire has a unique job, and because wires carry different amounts of current different distances under different conditions, there are many different types of wires (Figure 1).

Figure 1


High current
Stranded conductor
High temp. insulator
High voltage
Thick insulator
Light Conductor
Radio antenna lead
Braided shield
Thick insulator
Outer insulator
Light conductor
Low voltage/low current
Large conductor
Thin insulator

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Always keep one important rule in mind when you are working with wire: ***You should always replace a wire with a wire that has the identical qualities of the wire you are replacing***. Knowing something about wire will help you understand just how critical this rule is, but before studying about different types of wire, it's a good idea to review some principles you've already learned about conductors:

- How much resistance a wire has depends on what it's made of.
- Thick wire has less resistance than thin wire.
- Short strands of wire have less resistance than long ones.
- Current flowing in a wire produces heat.
- A wire that is hot has more resistance than a wire that is cool.
- When current flows through a conductor, some of the electrical energy is always changed to magnetic energy, surrounding the wire.

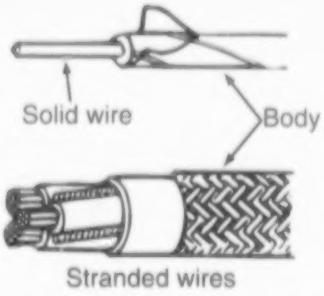
Wire materials—Most vehicle wires are made of copper, but you can also find wires made of aluminum, tin-plated brass, and even silver and gold. Table 1 shows the resistance values of some common metals. It's not hard to see why copper was chosen as a good material for wire.

Table 1

Material	Resistance (ohms per mil-foot)
Aluminum	17 Ω
Copper	10.4 Ω
Iron	60 Ω
Nichrome	600 Ω
Steel	75 Ω
Tungsten	33 Ω

Solid wire and stranded wire—All vehicle wires are either solid or stranded (a group of solid wires twisted or braided together). (Figure 2) If the current in the circuit is low and flexibility is not necessary, a *solid wire* can be used. Solid wire is a good conductor, but it isn't very flexible and can break under severe vibration or motion. Solid wire is sometimes used inside electrical components. However, if current flow is high or flexibility is necessary, *stranded wire* is used. Stranded wire, sometimes called *cable*, is very flexible and can withstand severe vibration. Stranded copper wire is the most common kind of wire used in vehicles.

Figure 2



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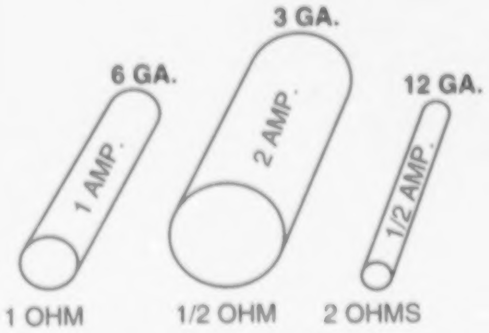
Twisted pair cable—Twisted pair are 2 insulated, stranded wires twisted together at 9 to turns per foot. The twisting helps protect the wires from electromagnetic energy. Electromagnetic energy can corrupt the data and pulses being sent to the different electronic modulators which would cause erratic responses from them. Twisted pair are usually found in speed sensor and data communication circuits.

Wire diameter—How much resistance a single strand of wire has and how much current it can conduct are also influenced by the wire's thickness, or *diameter* (the length of a straight line passing through the center of a cross section of the wire). Wire diameter is usually measured in AWG (American Wire Gauge) gauge size or in metric size (square millimeters) (Figure 3). You measure a single strand of wire with an outside micrometer. Table 2 shows some frequently used gauges and the resistance and current capacity of each gauge. The resistance and current capacity figures given in the table are based on copper wires.

Figure 3



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Note: When you measure the diameter of a wire, measure the diameter of the metal wire only—not the wire and the insulation covering the wire. Two wires of the same gauge may appear to be different thicknesses if the insulation on one is thicker than the insulation on the other.

Table 2

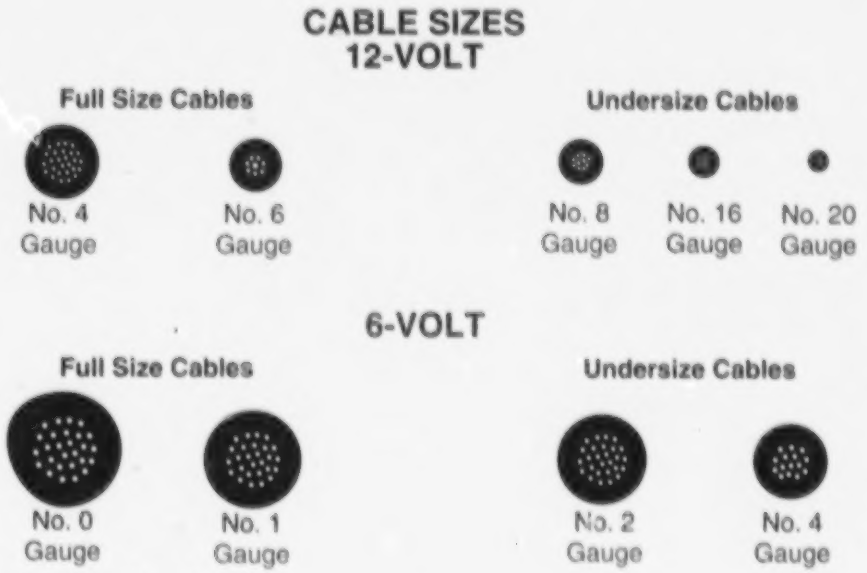
Single Strand Gauge Sizes

	Diameter (sq. in.)	AWG Size (gauge)	Metric Size (mm^2)	Resistance (Ω) per 1,000 ft.	Current (A) Capacity
Thinnest	.032"	20	.5	10.1	4
	.040"	18	.8	6.39	6
	.051"	16	1.0	4.02	8
	.064"	14	2.0	2.52	15
	.081"	12	3.0	1.59	20
	.102"	10	5.0	.9988	30
	.128"	8	8.0	.6281	40
	.162"	6	13.0	.3952	50
	.204"	4	19.0	.2485	60
Thickest	.258"	2	32.0	.1563	

Wire with a higher gauge number is thinner and will conduct less current than conductors with a lower gauge number. Most vehicle circuits use 14-, 16-, and 18-gauge wires. Battery cables are usually 2-, 4-, or 6-gauge. Some lighting, radio, and smaller accessory circuits use 14-, 16-, and 18-gauge wires.

Diameter of stranded wire—Determining the diameter of stranded wire (Figure 4) is more complicated than finding the diameter of solid wire, but to calculate the diameter, use Table 3 and complete the steps that follow it.

Figure 4


CABLE SIZES
12-VOLT
Full Size Cables
Undersize Cables
No. 4 Gauge
No. 6 Gauge
No. 8 Gauge
No. 16 Gauge
No. 20 Gauge
6-VOLT
Full Size Cables
Undersize Cables
No. 0 Gauge
No. 1 Gauge
No. 2 Gauge
No. 4 Gauge

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How to Measure the Gauge of Standard Wire (Cable)

1. Count the number of strands in the wire.
2. Measure the diameter of a single strand of the wire. (Use a micrometer and measure the diameter in thousandths of an inch.)
3. Using column A of the table, find the diameter of the wire you have measured and on the same line in column C, find its area.
4. Multiply the area of a single wire by the number of strands to get the total area.
5. In column C, find the figure that is closest to the total area obtained by step 4 and on the same line in column B, note the gauge number of a single wire having that area. This is the gauge of the stranded wire.

Example:

1. A stranded wire has 19 strands.
2. Each of the individual strands is 0.0112 inch in diameter.
3. The area of a strand that is 0.0112 in. in diameter is 127 circular mils.
4. The total area of the stranded cable is 19 x 127 circular mils. = 2413 total circular mils.

5. The closest figure in column C to 2413 total circular mils. is 2583 circular mils. 2583 circular mils is equal to a 16 gauge single wire. The gauge of the stranded wire is 16 gauge.

Table 3

Size and Area of Wire		
(A) Wire Diameter (inches)	(B) American Wire Gauge	(C) Circular MIL Area
.4600	0000	211600
.4096	000	167800
.3648	00	133100
.3249	0	105500
.2893	1	83690
.2576	2	66370
.2294	3	52640
.2043	4	41740
.1620	6	26250
.1285	8	16510
.1019	10	10380
.0808	12	6530
.0640	14	4107
.0508	16	2583
.0403	18	1624
.0319	20	1022
.0284	21	810.1
.0253	22	642.4
.0225	23	509.5
.0201	24	404.0
.0179	25	320.4
.0159	26	254.1
.0142	27	201.5
.0126	28	159.8
.0112	29	126.7
.0100	30	100.5
.0089	31	79.70
.0079	32	63.21
.0070	33	50.13
.0063	34	39.75
.0056	35	31.52
.0050	36	25.00

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Wire length—Wire length affects the resistance in a wire. Table 4 shows the gauge of wire needed to carry different levels (amps) of current for different distances from a 12 volt power source. If the circuit needs the amount of current in the first column to operate effectively and must travel in a wire the lengths across the top, you must choose a wire with the gauge listed where the number of amps and the length of the wire intersect.

Student Supplement 5

Table 4

Total Approximate Amps Needed in the Circuit	Wire Gauge (for Length in Feet)								
12 V	3'	5'	7'	10'	15'	20'	25'	30'	40'
1.0A	18	18	18	18	18	18	18	18	18
1.5A	18	18	18	18	18	18	18	18	18
2A	18	18	18	18	18	18	18	18	18
3A	18	18	18	18	18	18	18	18	18
4A	18	18	18	18	18	18	18	16	16
5A	18	18	18	18	18	18	18	16	16
6A	18	18	18	18	18	18	16	16	16
7A	18	18	18	18	18	18	16	16	14
8A	18	18	18	18	18	16	16	16	14
10A	18	18	18	18	16	16	16	14	12
11A	18	18	18	18	16	16	14	14	12
12A	18	18	18	18	16	16	14	14	12
15A	18	18	18	18	14	14	12	12	12
18A	18	18	16	16	14	14	12	12	10
20A	18	18	16	16	14	12	10	10	10
22A	18	18	16	16	12	12	10	10	10
24A	18	18	16	16	12	12	10	10	10
30A	18	16	16	14	10	10	10	10	10
40A	18	16	14	12	10	10	8	8	6
50A	16	14	12	12	10	10	8	8	6
100A	12	12	10	10	6	6	4	4	4
150A	10	10	8	8	4	4	2	2	2
200A	10	8	8	6	4	4	2	2	1

Wiring insulation—Almost all wiring in a vehicle is insulated to control the path of the current. The type of insulation for a wire depends on what material the wire is made from, the type of circuit it's in, the location of the circuit in the vehicle, the amount of current carried by the wire, and the level of voltage in the circuit.

The plastic PVC insulation used on most low current wires can protect the wire against extreme temperatures and from corrosion by water, gasoline, battery acid, antifreeze, and other chemicals found in and around automobiles. High-voltage wires for ignition system components and the battery use thick layers of fiber, glass, plastics, rubber, or other materials as insulation.

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Objective 22

Assignment Sheet 1—Explain What the Color Bands Found on Resistors Represent, and Use the Color Bands on a Resistor to Determine Its Resistance Value

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 12 of the 15 questions correctly per answers to Assignment Sheet 1	______

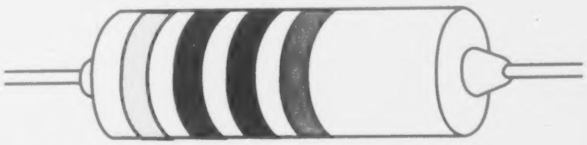
Basic Skills

Reading Writing Mathematics Critical Thinking

Introduction

Resistors are used to reduce the amount of current in a circuit. There are many reasons why current must be reduced in a circuit. For one thing, different loads require different amounts of current to operate. Somehow the current created by the vehicle's battery must be reduced to accommodate these different loads. Vehicle designers might want to allow a load to operate at different speeds (for example a heating/air-conditioning fan) or at different levels (as a dash light). They might need to reduce current a small amount (for an electrical load), or they might need to reduce current a great deal (for an electronic circuit). Regardless of *why* they are used to reduce current, resistors are the most common single component used in a vehicle.

Figure 1



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The color bands on resistors are a code that tells how much resistance (measured in ohms) the resistor will have on a circuit.

Resistors can be divided into two broad categories—*fixed resistors* (the most common type) and *variable resistors*. Fixed resistors (for a given voltage and load) can reduce the current only a single set amount. Variable resistors, under the same voltage and load, can reduce current by varying amounts.

Variable resistors—While fixed resistors place only a single preset amount of resistance on the circuit, *variable resistors* can adjust the amount of resistance they place on the circuit. There are several types of variable resistors. The only variable resistor that doesn't have any moving parts is the ballast resistor. ***Ballast resistors*** are made of a heat sensitive material whose resistance increases at higher temperatures. If the current is at one level, the ballast resistor has a low resistance, but if the current increases, the material in the ballast resistor gets hot and the resistance it places on the circuit will increase. ***Stepped*** (or tapped) ***resistors, potentiometers***, and ***rheostats***, are other types of variable resistors. How they work is discussed in the Information Sheet.

Fixed resistors—Fixed resistors, which have no moving parts, are made of materials that are poor conductors. When current flows in a poor conductor a great deal of the energy is transferred into heat—another form of energy.

In vehicles, resistors are often made of carbon, carbon film, metal film, some types of enamel, or various composite materials. Most fixed resistors are made of powdered carbon mixed with a glue-like binder. Carbon is cheap, predictable, and can be easily measured and molded into shape. However, if it is important that the resistor have special characteristics such as temperature stability, a very precise resistance tolerance, special noise characteristics, or a reduction in power as well as current, other materials may be used.

Fixed resistors come in various shapes and sizes. A resistor may be large or almost microscopic (such as resistors in electronic circuit chips). Resistors are measured in two ways.

- ***Watt rating***—The amount of power (measured in watts) the resistor can conduct without being damaged.
- ***Resistance value***—The amount of resistance (measured in ohms) the resistor will place on the circuit.

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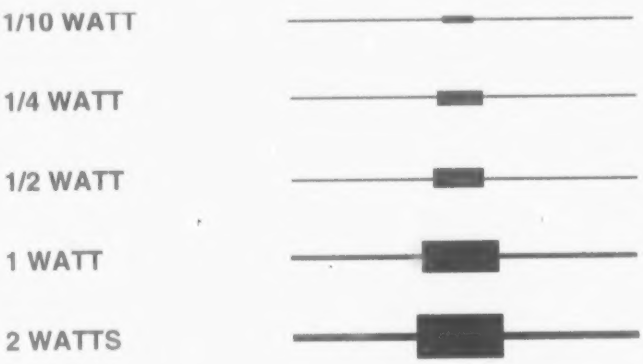
Figure 2



ACTUAL RESISTOR SIZE BY WATTS

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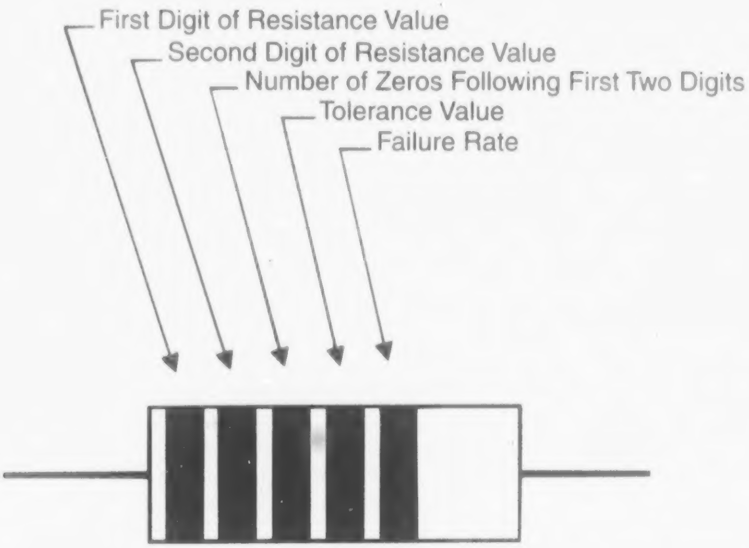
As the ***watt rating*** goes up, the size of the resistor also goes up (Figure 1). If the watt rating for a resistor is too low for the amount of current in the circuit, the resistor will burn up, just as any other circuit device would. When you replace a resistor, you should always choose a new resistor that has a watt rating the same or higher than the one you replace. With experience, you will learn to judge the appropriate watt rating by the size of the resistor.

A resistor's ***resistance value***, on the other hand, is unrelated to its size. The resistance value of a fixed resistor is sometimes stamped on the resistor, but usually you must determine the resistance value by looking at the color bands on the resistor. Resistors are banded according to a standardized code used by the entire industry. Each color represents either a number, a multiplier, a tolerance value, or a failure rate.

Look at the resistor in Figure 3. Notice that the color bands begin closer to one end of the resistor than they do to the other end. The "first" band is always considered *whichever band is closest to an end.* The color code chart below Figure 3 gives the meanings of the color bands found on fixed resistors. Don't worry about memorizing the chart. You'll probably use it enough to remember it naturally as you gain experience.

Figure 3

Resistor Color Codes


First Digit of Resistance Value
Second Digit of Resistance Value
Number of Zeros Following First Two Digits
Tolerance Value
Failure Rate

Color	1st or 2nd Band	3rd Band	4th Band	5th Band
	Digit	Number of zeros to add (multiplier)	Resistance Tolerance	Failure Rate
Black	0	0	-	-
Brown	1	1	±1%	1%
Red	2	2	±2%	.1%
Orange	3	3	-	.01%
Yellow	4	4	-	.001%
Green	5	5	-	-
Blue	6	6	-	-
Violet	7	7	-	-
Gray	8	8	-	-
White	9	9	-	-
Gold	-	none (.1)	±5%	-
Silver	-	none (.01)	±10%	-
None	-	-	±20%	-

How to Calculate the Resistance Value of a Fixed Resistor

Step 1: Locate the band that represents the first digit. It will be the band closest to the end.

Step 2: Look at the color of the first band and write down the number from the chart in Figure 3 that represents that color.

Step 3: Now look at the color of the second band and write down the number that color represents.

Step 4: Look at the color of the third band.

- Add the number of zeros indicated by the color on the third band to the number you determined in steps 2 & 3. For example, add no zeros if the color is black, one zero if it is brown, and so forth.
- If the third band is gold, ***multiply*** the number by .1.
- If the third band is silver, ***multiply*** the number by .01.

Step 5: Look at the color of the fourth band and write the corresponding percentage immediately after the value you calculated in the previous steps. Be sure and put the ± sign before the percentage.

This percentage is the ***resistance tolerance***—the percentage above or below its resistance value a resistor can vary and still operate correctly. There are no perfect resistors. Manufacturers put a tolerance on a fixed resistor to state that the resistor will be within a certain range of the value of the resistor.

Example: A resistor with an orange first band, a yellow second band, a black third band, and a fourth gold band, has a resistor value of 34 with a ± 5% tolerance.

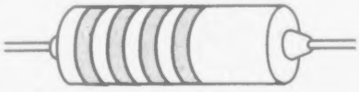
34 x 5% (.05) = 1.7
34 - 1.7 = 32.3
34 + 1.7 = 35.7

This resistor has a resistance value between 35.7 and 32.3. You have to make sure the circuit you are working with is capable of handling this resistance range. The lower the tolerance, the higher the cost of the resistor.

Step 6: Look at the color of the fifth band and write down the corresponding percentage. This is the failure rate of the resistor. The lower the failure rate the higher the cost of the resistor.

Note: Some resistors do not specify a failure rate and have only 4 bands.

Figure 4



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Assignment Sheet 1

The problem:

Find the resistance value of the resistor shown in Figure 4 if the colors of the four bands are as follows from left to right: red, violet, brown, brown.

Solving the problem:

Step 1: The first band is the one on the left of the picture. (The band on the left side is closer to the end than the band on the right side.)

Step 2: The first digit is 2. (red band = 2)

Step 3: The second digit is 7. (violet band = 7)

Step 4: One zero should be added to the number 27, making it 270. (brown band = add 1 zero)

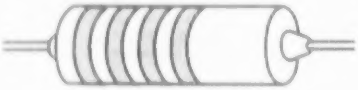
Step 5: Write ± 1% after the number 270. 270 Ω ± 1% (brown = a tolerance of ± 1%)

Answer: 270 Ω ± 1%

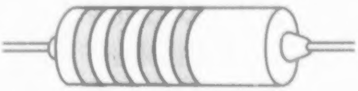
Directions

Put a box around your answers to the following questions. Show your work.

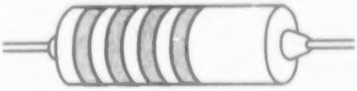
1. What is the resistance value of the resistor pictured below if the bands (from left to right) are: green, blue, orange, red?



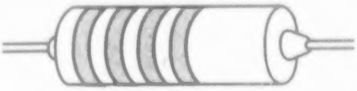
2. What is the resistance value of the resistor pictured below if the bands (from left to right) are: brown, black, red, brown?



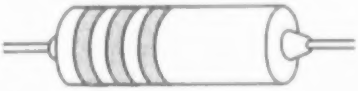
3. What is the resistance value of the resistor pictured below if the bands (from left to right) are: gray, orange, orange, silver?



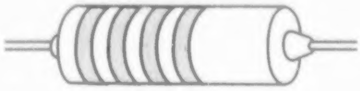
4. What is the resistance value of the resistor pictured below if the bands (from left to right) are: black, violet, black, gold?



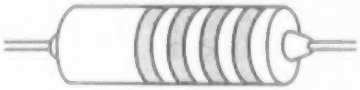
5. What is the resistance value of the resistor pictured below if the bands (from left to right) are: green, white, brown?



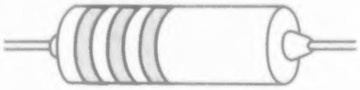
6. What is the resistance value of the resistor pictured below if the bands (from left to right) are: red, blue, gold, brown?



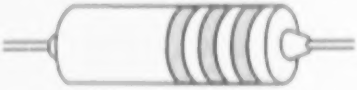
7. What is the resistance value of the resistor pictured below if the bands (from left to right) are: red, red, gray, yellow?



8. What is the resistance value of the resistor pictured below if the bands (from left to right) are: black, white, silver?



9. What is the resistance value of the resistor pictured below if the bands (from left to right) are: orange, yellow, black?



10. What color bands are on a resistor with a resistance value of 18 Ω ± 5%? List the color of the 1st band first.

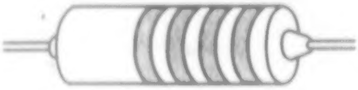
11. You need to replace a resistor with a resistor rating of 60 ± 2%. You only have a few resistors on hand. You find a resistor whose bands are (from 1st band): blue black, gold, red. Can you use this resistor to replace the old one? Explain why you gave this answer.

12. You find another resistor to replace the 60 ± 2% resistor. Its bands are (from 1st band): blue, black, black, red. It seems slightly larger than the old resistor. Can you use this resistor to replace the old one? Explain why you gave this answer.

Assignment Sheet 1

13. You need to find a resistor with a 2 Ω ± 5% resistor rating to replace an old one. What color are the bands on the resistor you are looking for? List the color of the 1st band first.

14. What is the resistance value of the resistor pictured below if the bands (from left to right) are: red, orange, orange, blue?



15. What color bands are on a resistor with a resistance value of 8,100 Ω ± 20%? List the color of the 1st band first.

Objective 23

Assignment Sheet 2—Determine Correct Replacement Fuses

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per answers to Assignment Sheet 2	______

Basic Skills

Reading Writing Mathematics Critical Thinking

Introduction

Fuses are the most common type of protection device used on electrical circuits. But, like fusible links, they only do their job of protecting the rest of the circuit devices when they are destroyed. Fortunately, fuses are easily inspected and replaced.

How do you know if a fuse has blown?

You won't know for sure that a fuse has blown until you look at it, but usually the first sign that a fuse has blown is that the load(s) on the circuit do not work: a lamp doesn't go on, the horn doesn't sound, the radio won't operate. But sometimes the fact that a fuse is blown may not be immediately apparent. *If any electrical or electronic equipment is not working, it's always a good idea to check the fuse that serves the circuit with a test light before doing anything else.* The first step in replacing a fuse is to locate the fuse or other protection device for the circuit and see if it's blown.

Locating the fuse box

Fuses may be located in several different places on a vehicle. How easy a fuse is to get to often depends on the likelihood of the fuse blowing and whether the vehicle manufacturer is comfortable letting the vehicle owners replace the fuse when it blows. Most fuses are found in a fuse box, but fuses can also be located in a wiring harness, junction box, or mounted near a relay. Vehicles generally have somewhere between one and four different fuse boxes. Older vehicles tend to have fewer fuse boxes than newer ones.

Fuses that protect circuits serving loads controlled inside the passenger compartment are typically located in a fuse box inside the vehicle. This is most often located in a fuse box inside the vehicle. This is most often located under the instrument panel, but sometimes it's found in the storage box, behind a kick panel, or in various other locations. Fuses that protect circuits serving loads that are controlled outside the passenger compartment are usually located in a fuse box or power distribution box in the engine compartment. A power distribution box contains both fuses and relays. If you have any trouble locating the fuse box, check the vehicle's owner's manual or service manual.

Finding a blown fuse

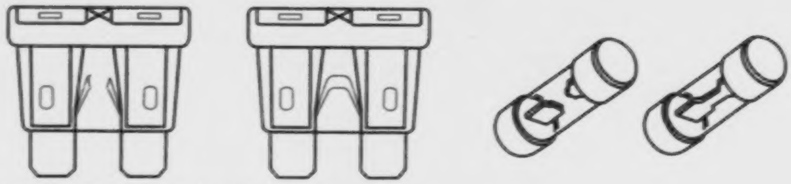
Once you have located the fuse box, the circuits each fuse protects are normally listed on the cover of the box (Table 1). Use the information on the cover to find the fuse you suspect to being blown. *If the information is not available from the cover, consult the vehicle's owner's manual or service manual.*

Table 1

1	**15A**	Hazard warning lights
2	**15A**	Dash light, tail, side marker and license lights
3	**20A**	Heated mirror grid
4	**15A**	Horn and brake lights
5	**15A**	Cigar lighter, interior light, and key reminder buzzer
6	**15A**	Windshield wiper and washer
7	**20A**	Heater and radio
8	**15A**	Meter, back-up light, seat belt warning buzzer, turn signal, and heated window grid light
9	**15A**	Kick-down and choke relay
10	**15A**	Ignition, emission, and fuel pump

To determine if the fuse is blown, pull the fuse from the box and look through the plastic or glass at the metal strip inside the fuse (Figure 1). If the fuse is blown, the strip will be separated in the middle where it has melted. A fuse cannot be reused if it has blown. *It must be replaced.*

Figure 1



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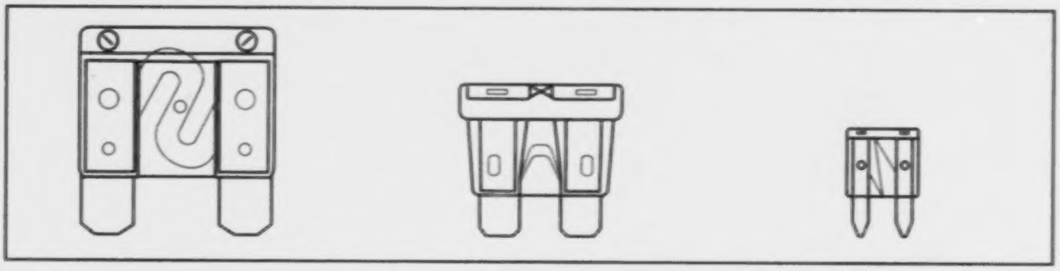
Choosing a replacement fuse

Fuses are designed to carry no more than a preset amount of current and to blow if the current is higher than this amount. The maximum amount of current a fuse will conduct without melting (its *fuse rating*) is rated in amps. The fuse rating required for a fuse protecting a circuit is often printed on the fuse box next to the number of the circuit. The fuse rating is also usually printed on the fuse—on the metal end terminal of glass fuses and on the top of blade fuses. If *15A* is printed on a fuse, it means the fuse will handle 15 amps of current without blowing.

Blade fuses come in three sizes—autofuses, maxifuses, and minifuses. The fuse ratings of blade fuses are identified by a standardized color code (Figure 2).

Figure 2



Maxifuse

Current Rating (in amps)	Color
20	Yellow
30	Green
40	Amber
50	Red
60	Blue
70	Brown
80	Natural

Autofuse

Current Rating (in amps)	Color
3	Violet
5	Tan
7.5	Brown
10	Red
15	Blue
20	Yellow
25	Natural
30	Green

Minifuse

Current Rating (in amps)	Color
5	Tan
7.5	Brown
10	Red
15	Blue
20	Yellow
25	White
30	Green

Assignment Sheet 2

When replacing a fuse, *it is important to determine the correct replacement size and replace the fuse with one of the same type, size, and fuse rating as the original fuse.*

- A fuse with *too high* a rating will allow too much current in the circuit—which will damage or destroy the other circuit devices on the circuit.
- A fuse with *too low* a rating will blow when the current is too low to allow the other circuit devices on the circuit to do their jobs.

Directions

Use the information in this Assignment Sheet to answer the following questions. Write your answers in the blanks provided.

1. What color fuse would replace a 15-amp minifuse?

   ____

2. You don't have a service manual in your vehicle, and you need to replace a blade fuse. Name four places you could look to find the fuse rating for the blade fuse your need.

   - ____
   - ____
   - ____
   - ____

3. Where is the most likely location to find the fuse for the air-conditioner blower motor? Be specific.

   ____

4. What maximum level of current will be allowed by an amber maxifuse?

   ____

5. You need a 20-amp blade fuse. You find a yellow fuse, but it's a little smaller than the one you removed. Can you use it? Explain your answer.

   ____

   ____

   ____

6. You find a glass fuse lying on a work table. How would you determine its fuse rating?

   ____

7. You remove a blue maxifuse and replace it with a green one. Will the circuit function correctly under normal current? What result would you expect?

8. You remove a red minifuse and replace it with a white one. Will the circuit function correctly at 20-amp current? What result would you expect?

9. If the fuse box in your car uses minifuses and has the same information as the fuse box lid in Table 1, what color fuses would you keep on hand in case of an emergency that causes you to blow a fuse?

10. What would be the initial result of replacing a green maxifuse with a green autofuse?

Objective 24

Assignment Sheet 3—Use Wire Color and Circuit Identification Codes to Locate Circuit Information

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per answers to Assignment Sheet 3	______

Basic Skills

Reading Writing Mathematics Critical Thinking

Introduction

As you learned in Supplement 5, vehicle wires come in a variety of types, sizes, and materials to make them suitable for the amount of current they must carry. Looking under the hood of a car, the job of finding the right circuits and wires can sometimes appear to be an impossible task. Fortunately, vehicle wires are color coded, and circuits and other wiring features are numbered on wiring diagrams to help you locate the correct wires and circuits. Unfortunately, these codes are not standardized in the industry. You must always use the wire color and circuit identification coding system used by the manufacturer of the vehicle you are servicing.

Wire color and circuit identification codes are not only used to help you find the right circuits for electrical service and repair, they are used to help you select the correct replacement parts and for other purposes as well. For example, many manufacturers use them in cost and quality controls. Before replacing a defective device that is under warranty, manufacturers may require that you report the circuit on which the device was located before they will reimburse the shop for the replacement. In this way, they can identify, track, and correct any design problems that may be causing such incident.

Wire Color Codes

The insulation covering wires is colored to make locating a wire in the vehicle and on a wiring diagram easier. Table 1 shows some of the common abbreviations used for wire colors.

Assignment Sheet 3

Table 1

Color	Abbreviations		
Alumium	AL		
Black	BLK	BK	B
Blue (Dark)	BLU DK	DB	DK BLU
Blue (Light)	BLU LT	LB	LT BLU
Brown	BRN	BR	BN
Glazed	GLZ	GL	
Gray	GRA	GR	G
Green (Dark)	GRN DK	DG	DK GRN
Green (Light)	GRN LT	LG	LT GRN
Maroon	MAR	M	
Natural	NAT	N	
Orange	ORN	O	ORG
Pink	PNK	PK	P
Purple	PPL	PR	
Red	RED	R	RD
Tan	TAN	T	TN
Violet	VLT	V	
White	WHT	W	WH
Yellow	YEL	Y	YL

In addition to solid colored wires, manufacturers may also use wires with a tracer such as stripes, hashmarks, or dots. In most wire color codes, the first group of letters designates the base color of the insulation, and a second group of letters, if present, indicates the color of the tracer. For example, a wire designated R/BK would be red with a black tracer.

Ford uses the following tracer combinations:

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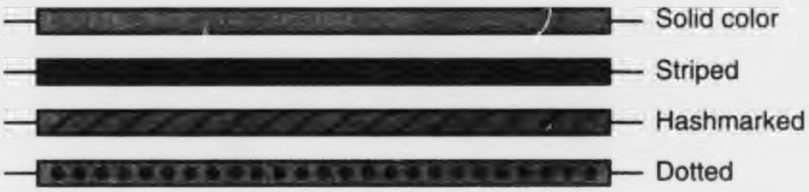
Figure 1

Wire Identification


Solid color
Striped
Hashmarked
Dotted

(D) Dot
(H) Hashmark
Stripe is understood

Examples:
BK - Solid Black
BR-Y - Brown with yellow stripe
BK-Y H - Black with yellow hashmarks
O-BK D - Orange with blacks dot

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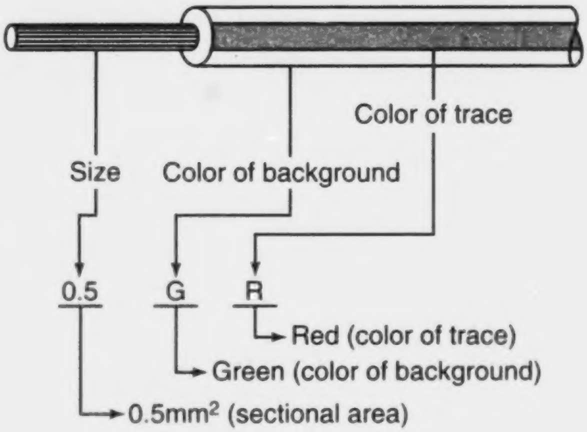
Figure 2


Color of trace
Size
Color of background
0.5
G
R
Red (color of trace)
Green (color of background)
0.5mm² (sectional area)

Circuit Identification Codes

A circuit identification code is a system that uses a number-letter method to identify specific wires, connectors, splices, grounds, and other wiring diagram features. The features a manufacturer's wiring identification code identifies varies (as does the code) from manufacturer to manufacturer. All manufacturers identify each wire—describing the color and the circuit of each wire. Some manufacturers also identify the diameter of the wire and the branch of the circuit the wire is on. You must use the coding system used by the manufacturer of the vehicle you are working on.

Several manufacturers use the circuit identification code shown in Figure 3. Notice that they identify both the main line circuit and the branch (if any) of the circuit in their circuit identification code (Table 2). Also notice that they state the wire diameter by giving the gauge of the wire. The asterisk (*) indicates that the second color is on the wire's tracer. Splice locations are indicated on wiring diagrams by a diamond with the splice circuit code in it. If there is more than one splice on the circuit, a small box with the splice number in it is connected to the diamond.

Figure 3

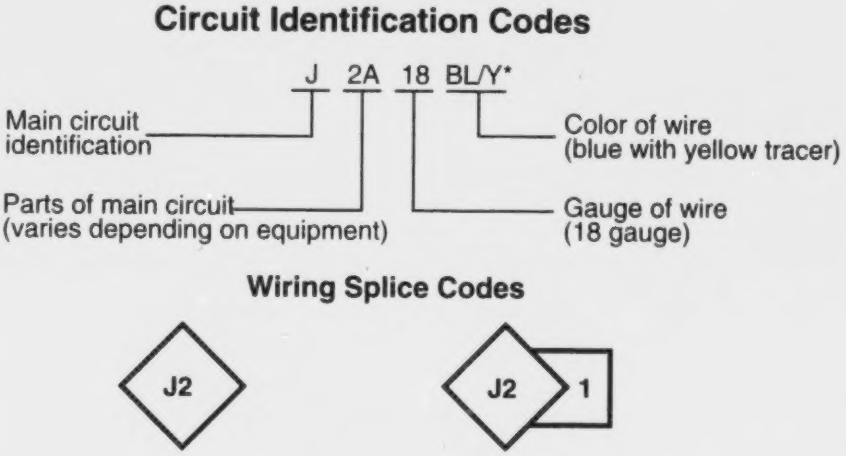

Circuit Identification Codes
J 2A 18 BL/Y*
Main circuit identification
Parts of main circuit (varies depending on equipment)
Color of wire (blue with yellow tracer)
Gauge of wire (18 gauge)
Wiring Splice Codes
J2
J2
1

Table 2

Main Circuit Identification Codes

A	Battery Feed(i.e. fuselink feeds, starter feeds, starter relay
B	Brakes
C	Climate Control (A/C, heater, E.B.L. and heated mirror related circuits)
D	Diagnostic Circuits
E	Dimming Illumination Circuits
F	Fused Circuits (non-dedicated multi-system feeds)
G	Monitoring Circuits (gauges. clocks, warning devices)
H	Open
I	Not used as a circuit designator
J	Open
K	Engine Logic Module Control Circuits
L	Exterior Lighting Circuits
M	Interior Lighting Circuits (dome, courtesy lamps, cargo lamps)
N	ESA Module Electronic Circuits
O	Not used as a circuit designator
P	Power Options (battery feed) (i.e. seats, door locks, mirrors, deck lid release, etc.
Q	Power Options (ignition feed) (i.e. windows, mirrors)
R	Passive Restraint
S	Suspension and Steering Circuits
T	Transmission, Differentials, Transfer Case, and Starter System
U	Open
V	Speed Control and Wash Wipe Circuit
W	Open
X	Sound Systems (i.e. radio and horn)
Y	Open
Z	Grounds (B-)

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GM wiring diagrams always list the wire diameter in square millimeters rather than wire gauge. For example, three black wires of .8 mm^2 are identified as ".8Blk" and their circuit numbers (72, 52, & 50) are to the right of each wire. The splice where the three wires come together is identified as splice 114 (S114). The ground used for the circuit is ground 117 (G117).

The Society of Automotive Engineers (SAE) has proposed a system to standardize the color and circuit identification codes on all circuit diagrams so all vehicle manufacturers will use the same system, but their proposals have not yet been approved. *You must always use the color and circuit identification coding system used by the manufacturer of the vehicle you are servicing.*

Directions

Use the information in this Assignment Sheet to answer the following questions. Write your answers in the blanks provided.

1. What color is a wire that is marked DG/V?

   ____

2. Identify, as completely as possible, a wire labled L 2B 10 T/O* on a wiring diagram of a Chrysler vehicle?

   ____

   ____

   ____

3. Describe a wire from a Ford vehicle that is marked DB-W.

   ____

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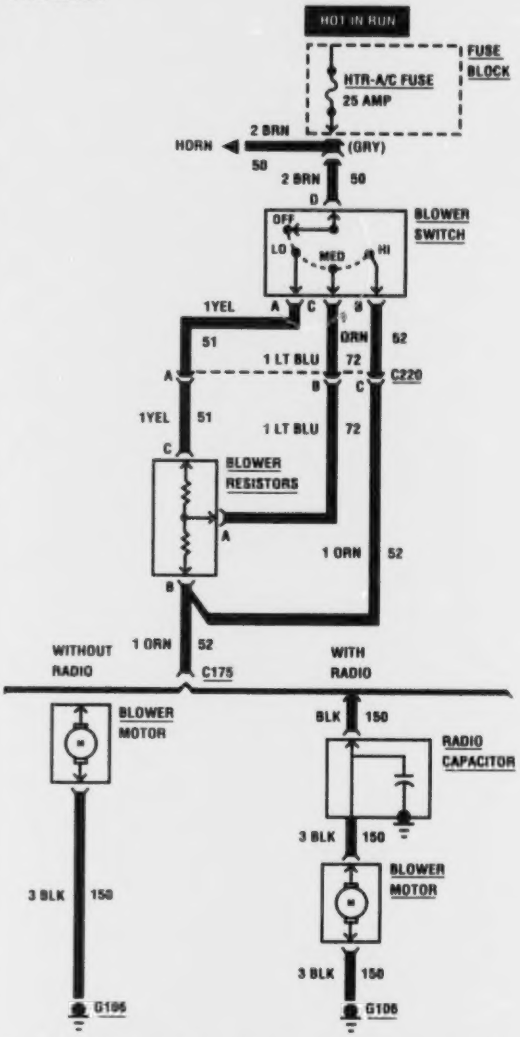
Figure 4

Heater


HOT IN RUN
FUSE BLOCK
HTR-A/C FUSE
25 AMP
2 BRN
HORN
(GRY)
50
2 BRN
50
D
BLOWER SWITCH
OFF
LO
MED
HI
1YEL
A
C
B
51
ORN
52
1 LT BLU
72
A
C220
B
C
1YEL
51
1 LT BLU
72
C
BLOWER RESISTORS
A
1 ORN
52
B
WITHOUT RADIO
1 ORN
52
C175
WITH RADIO
BLOWER MOTOR
BLK
150
RADIO CAPACITOR
3 BLK
150
BLOWER MOTOR
3 BLK
150
3 BLK
150
G106
G106

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Use the above illustration to answer the remaining questions.

4. You need to check the vehicle's heater blower. What color is the wire between the fuse block and the blower switch?

5. If you wanted to check the horn, what color wire would you look for coming from the fuse block?

____

6. What size is the wire between the blower resistors and the connector to the blower motor?

____

7. What is the number of the ground the heater blower uses?

____

8. What is the circuit number between the high speed setting on the blower switch and the connector to the blower motor?

____

9. What colors are the wires coming out of the blower switch?

____

10. You need to replace the wire from the blower motor to the ground. What color and gauge wire do you need?

____

Objective 25

Assignment Sheet 4—Use Wiring Diagrams to Locate Information about Circuits

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 16 of the 20 questions correctly as per answers to Assignment Sheet 4	______

Basic Skills

Reading Writing Critical Thinking

Introduction

A wiring diagram is a road map for finding your way around a vehicle's electrical system. Every electric or electronic circuit, component, and circuit device is on a wiring diagram. If a wiring diagram is the map, electricity is the unseen traveler on that map. The wiring diagram tells where this traveler—electricity—will begin the trip (the power source), the roads it will travel (the conductors), the traffic signals and speed limits it must obey (the control devices), the traffic cops that make it stop if it's about to destroy something (the protection devices), where the traveler goes to work (the loads), and where it goes when its work is done (the grounds).

Like road maps, wiring diagrams can show the entire system or only a small part of the system. But although wiring diagrams can show you the location of these many parts, they can't tell you why the electricity behaves as it does. That's your job and that's why you must know how electricity behaves and how each circuit device alters and uses that behavior.

In this unit you have learned some of the electrical symbols that are used to represent various common circuit devices and features found in wiring diagrams. You have learned to use wire color and circuit identification codes to help you find your way around. You have learned to use wire color and circuit identification codes to help you find your way around. You have also learned that, although there are some similarities, these symbols, features, and codes are not standardized in the trucking industry.

Reading wiring diagrams may seem difficult at first, but with each experience, you will gain more confidence until it's as easy as, well, reading a road map.

Reading Wiring Diagrams

When reading a wiring diagram, keep the structure of a basic circuit in mind. A circuit begins at the positive side of the power source, travels through conductors and protection and control devices to the load device, then returns to the negative side of the power source through conductors and possibly more control devices. If the circuit is not operating properly, the load device will malfunction and troubleshooting should be concentrated on the malfunctioning circuit.

Single line diagrams

A single line diagram allows you to see the entire circuit, including the load device and all its control and protection devices. By locating the malfunctioning load device, you can trace the circuit in one direction to the power source and in the other direction to the ground source through all the control and protection devices. Each control and protection device can then be checked for correct operation and serviceability. Since all devices are clearly shown, this type of diagram is the best one to use for troubleshooting.

Harness diagrams

On each leg of the harness, you can see the conductors, their wire number or description, and their placement in the connectors along with the connector and terminal manufacturer's name and part number. To trace a conductor through the harness, you have to look at each connector to find that particular number. There may be a wire splice within the harness, so one wire may splice out to several wires that lead to several connectors. Usually there will be a schedule showing wire numbers and their colors.

The numbers on the harness body represent the length of that particular run of harness. If you add up all the lengths from one end of the harness to the other, they will equal the total length of the harness. If the harness adds up to 35' and the vehicle is 36' long, then you can assume that this harness is running the full length of the vehicle. By using the lengths of harness, you can determine approximately where a connector may be located in a vehicle.

This type of diagram is not suitable for troubleshooting by itself because you cannot see all the conductors, control or protection devices, or load devices. However, a harness diagram used in conjunction with a single line or ladder diagram, can be a great troubleshooting tool.

Ladder diagrams

On ladder diagrams, the left vertical leg is normally the positive power source. The right vertical leg is normally the ground source, and each horizontal rung of the ladder is an individual basic circuit consisting of conductors, and control, protection, and load devices.

Ladder diagrams can be difficult to read and use for troubleshooting because all related load and protection devices may not be on the same rung. A relay may have a coil located on one rung, a normally closed contact might be on another rung, and a normally open contact might be on still another rung. If this is the case, there will be a reference (for example, "C1") next to all the related devices. The problem is that you will not know how many related devices there might be, and you will have to search the entire drawing to find them all.

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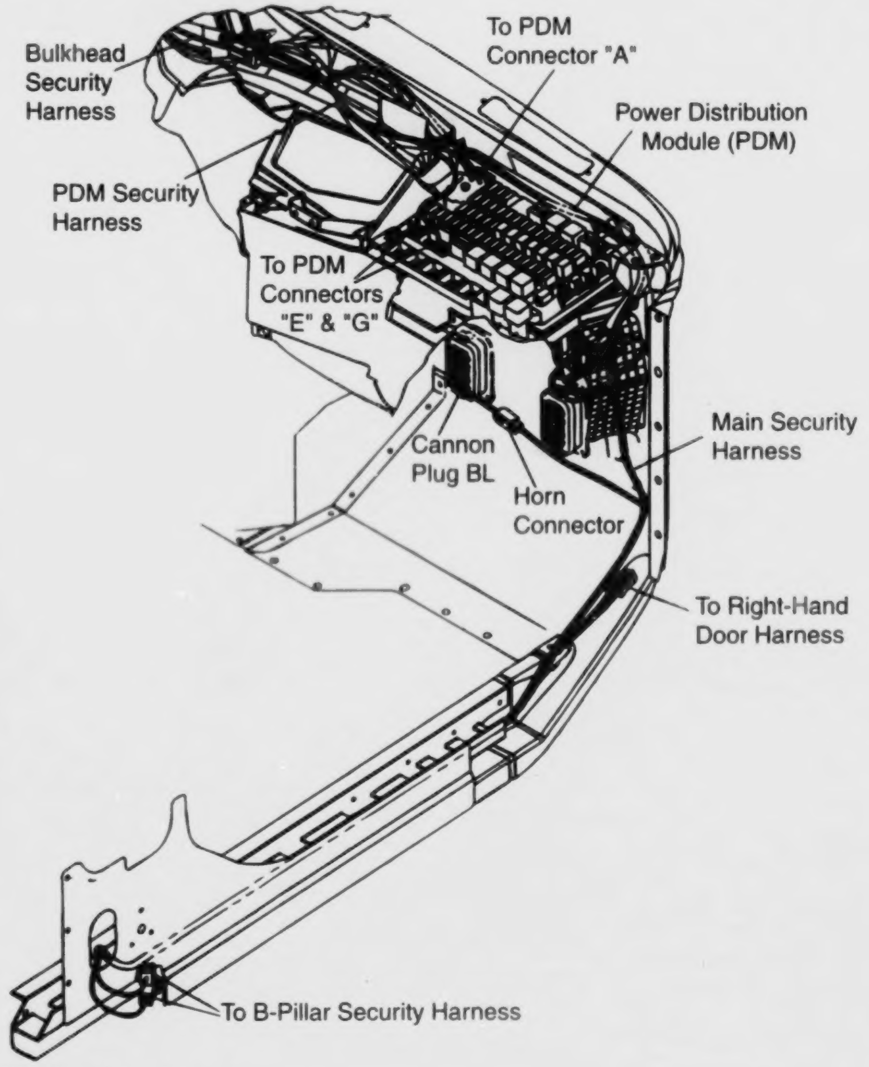
Routing diagrams

Routing diagrams are different than other types of wiring diagrams. They are more like a picture that shows where a harness is actually located in the vehicle, and where connectors, grounds, and certain components are located along the route of the harness.

Routing diagrams are useful for finding where harnesses and connectors are located to isolate problems with a particular component or section of harness. Routing diagrams should be used in addition to one of the other types of diagrams because they don't provide the technician with enough information to troubleshoot a problem.

Figure 1—Routing Diagram


Bulkhead Security Harness
To PDM Connector "A"
Power Distribution Module (PDM)
PDM Security Harness
To PDM Connectors "E" & "G"
Main Security Harness
Cannon Plug BL
Horn Connector
To Right-Hand Door Harness
To B-Pillar Security Harness

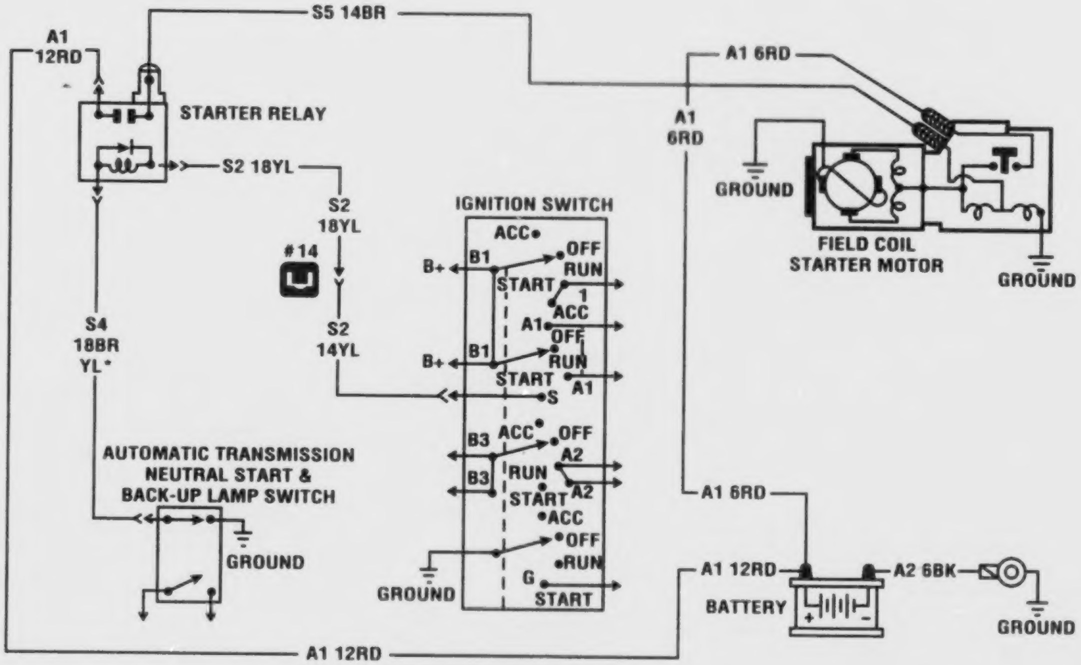
Courtesy of Freightliner LLC

Assignment Sheet 4

Directions

Use the information you have learned in this unit and the wiring diagrams given here to help you answer the following questions.

Wiring Diagram A—Single Line Diagram


S5 14BR
A1 12RD
STARTER RELAY
S2 18YL
S2 18YL
#14
S2 14YL
S4 18BR YL*
AUTOMATIC TRANSMISSION NEUTRAL START & BACK-UP LAMP SWITCH
GROUND
IGNITION SWITCH
ACC
B+
B1
OFF
RUN
START
1
ACC
A1
B+
B1
OFF
RUN
START
A1
S
B3
ACC
OFF
A2
B3
RUN
START
A2
ACC
OFF
RUN
G
START
GROUND
A1 12RD
A1 6RD
A1 6RD
GROUND
FIELD COIL STARTER MOTOR
GROUND
A1 6RD
A1 12RD
BATTERY
A2 6BK
GROUND

Starting System Circuit

Used with permission of DaimlerChrysler Corp.

Use wiring diagram A to help you answer the following questions. Write your answers in the blanks provided.

1. What kind of a control device is the automatic transmission neutral start and back-up lamp switch?

____

2. Name the sealed circuit devices shown on this diagram.

____

____

____

____

3. What color and gauge is the wire from the battery to the starter relay?

____

4. What is the number of the circuit that has a connector that connects two wires?

____

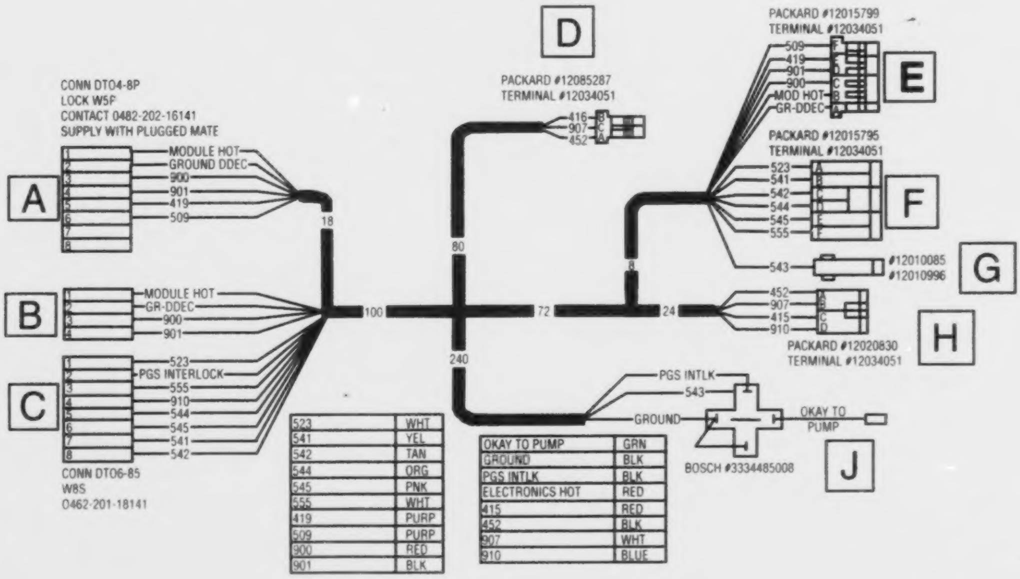
5. What kind of control device is the ignition switch?

____

6. Are there any electronic circuit devices on this circuit? If so, what are they and where are they?

____

Wiring Diagram B—Harness Diagram


D
PACKARD #12085287
TERMINAL #12034051
416 B
907 C
452 A
PACKARD #12015799
TERMINAL #12034051
509 F
419 E
901 D
900 C
MOD HOT B
GR-DDEC A
E
CONN DT04-8P
LOCK W5P
CONTACT 0482-202-16141
SUPPLY WITH PLUGGED MATE
A
1 MODULE HOT
2 GROUND DDEC
3 900
4 901
5 419
6 509
7
8
18
80
PACKARD #12015795
TERMINAL #12034051
523 A
541 B
542 C
544 D
545 E
555 F
F
8
543
#12010085
#12010996
G
B
1 MODULE HOT
2 GR-DDEC
3 900
4 901
100
72
24
452 A
907 B
415 C
910 D
H
PACKARD #12020830
TERMINAL #12034051
240
C
1 523
2 PGS INTERLOCK
3 555
4 910
5 544
6 545
7 541
8 542
CONN DT06-85
W8S
0462-201-18141
PGS INTLK
543
GROUND
OKAY TO PUMP
BOSCH #3334485008
J

523	WHT
541	YEL
542	TAN
544	ORG
545	PNK
555	WHT
419	PURP
509	PURP
900	RED
901	BLK

OKAY TO PUMP	GRN
GROUND	BLK
PGS INTLK	BLK
ELECTRONICS HOT	RED
415	RED
452	BLK
907	WHT
910	BLUE

Use wiring diagram B to help you answer the following questions. Write your answers in the blanks provided.

7. What is the length between connector B and connector H?

____

8. What is the color of wire #419?

____

9. What connectors share the same wire #543?

____

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10. I'm troubleshooting a problem on circuit "Ground DDEC." Where would I find it?

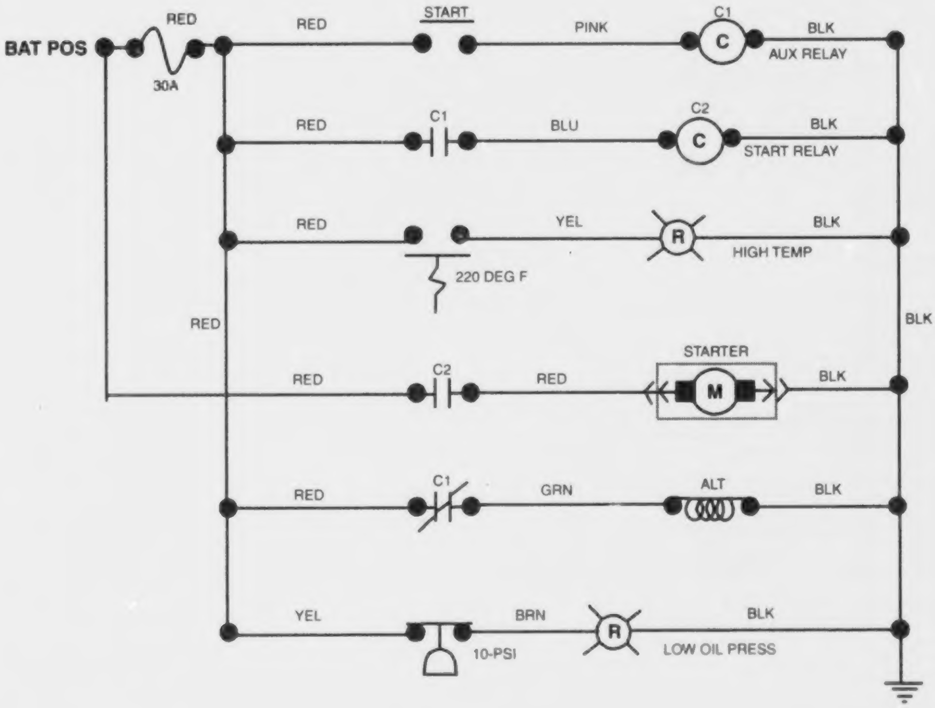
11. What is the length of harness between connectors D and J?

12. "I found an open in circuit '907' but I can't read the wire number." What else can I use to locate the wire and its location?

13. What is the location of each connector where wire #901 terminates?

14. What kind of terminals can you use at connector #12020830?

Wiring Diagram C—Ladder Diagram


BAT POS
RED
30A
RED
START
PINK
C1
C
BLK
AUX RELAY
RED
C1
BLU
C2
C
BLK
START RELAY
RED
YEL
R
BLK
HIGH TEMP
220 DEG F
RED
BLK
STARTER
RED
C2
RED
M
BLK
RED
C1
GRN
ALT
BLK
YEL
BRN
R
BLK
10-PSI
LOW OIL PRESS

Use wiring diagram C to help you answer the following questions. Write your answers in the blanks provided.

15. Explain what the C1 coil is and what it controls.

____

16. At what temperature will the High Temp light come on?

____

17. At what pressure will the Low Oil Press light come on when the engine is running?

____

18. Explain the sequence that has to happen before the starter will energize.

____

19. What happens to the alternator when the engine is starting?

____

20. What size is the circuit protection device for the High Temp circuit?

____

Objective 26

Assignment Sheet 5—Use Your Knowledge of Electric/Electronic Theory and Circuit Devices to Predict Changes in Current, Voltage and Resistance in a Series Circuit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 10 of the 13 questions correctly per answers to Assignment Sheet 5	______

Basic Skills

Reading Writing Critical Thinking

Introduction

So far you've learned that "technicians aren't even able to hook up the test equipment correctly unless they understand in advance what's probably happening" to the electricity in the circuit. Now that you know the functions of the various circuit elements and how some common circuit devices work, this information should help you predict changes in the current, voltage, and resistance in a circuit.

Directions

Use your knowledge of electrical/elelectronic theory and circuit devices to predict the changes that would result in each situation. You may assume that all of these questions apply to a *series* circuit. Write your answers in the blanks provided.

1. What would the effect be on the current in a circuit if the ground wire is unscrewed?

   ____

   ____

2. If another lamp were added to a circuit—would the resistance in the circuit increase, decrease, or stay the same?

   ____

Assignment Sheet 5

3. If another lamp were added to a circuit—would the voltage applied to the circuit increase, decrease, or stay the same?

4. If another lamp were added to a circuit—would the current in the circuit increase, decrease, or stay the same?

5. A circuit operates correctly using a yellow autofuse. What would be the affect on current if the yellow fuse were replaced with the same size red fuse?

6. What would the effect on current in a circuit be if you replaced a resistor with a resistance value of 25Ω wth one that has a resistance value of 5Ω?

7. Would you expect the current to a diode to be higher or lower than the current to a motor?

8. What would be the effect on current in a circuit if a Darlington pair were installed on the circuit?

9. What would happen to the current in a circuit if you replaced a 5 inch 8 gauge wire with a 5 inch 16 gauge wire?

10. You forgot to replace a resistor on a circuit when you repaired it. Now the circuit breaker keeps tripping the circuit. Why?

11. You replace a mirror that has a heated grid with 1 foot of metallic grid with a new mirror that has a heated grid with 2 feet of metallic grid. What will happen to the resistance in the circuit?

12. If you install a capacitor in a circuit, how would you expect the current to change?

13. What would be the effect on current if a mercury switch were entirely drained of mercury?

Objective 27

Job Sheet 1—Inspect, Test, and Replace Spike Suppression Diodes/Resistors

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job Ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Spike suppression (clamping) diodes protect integrated circuits in computers, display devices, and high load switching devices. Most suppression devices are incorporated in delicate circuit boards within the computer.

Solenoid and relay type devices utilize a coil that develops an electromagnetic field (read Student Supplement 3). When current is turned off to the coil, the field collapses, inducing a voltage spike, or surge. Since voltage spikes can damage computer circuits and switches, spike suppression diodes are placed in a circuit in parallel to the coil. One use of a spike suppression diode is on air-conditioning compressor clutches.

The measurement of transient voltage spikes and the selection of suppression devices is best left to electrical engineers who have the knowledge and experience to review the entire electrical system. A suppression device rated too low or high could damage the circuit by bleeding voltage off too early or allowing the voltage to get too high. However, service technicians can replace suppression devices on a one-for-one basis after consulting the service manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Job Sheet 1

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Unit 3

Developing Basic Diagnosis & Repair Skills

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Objective Sheet

Unit Objective

After completing this unit, the student should be able to demonstrate basic diagnosis and repair skills using electrical test equipment, calculate voltage, voltage drop, current, and resistance in circuits, and make repairs to terminals, connectors, and conductors. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to developing basic diagnosis and repair skills to their correct definitions.
2. Match types of common circuits to their electrical characteristics.
3. Describe common problems with electrical circuits.
4. Distinguish among types of electrical diagnostic instruments.
5. Arrange in order the steps in electrical troubleshooting.
6. Arrange in order the steps in soldering.
7. Complete statements concerning guidelines for soldering.
8. Identify types of circuits and circuit devices on a circuit. (Assignment Sheet 1)
9. Perform calculations using units of electrical measurement. (Assignment Sheet 2)
10. Prepare to measure current, voltage, resistance, and frequency with a multimeter. (Assignment Sheet 3)
11. Calculate resistance in sample circuits. (Assignment Sheet 4)
12. Calculate current in sample circuits. (Assignment Sheet 5)
13. Calculate voltage drop in sample circuits. (Assignment Sheet 6)
14. Calculate voltage in sample circuits. (Assignment Sheet 7)
15. Calibrate and make functionality tests on electrical diagnostic instruments. (Job Sheet 1)
16. Check electrical/electronic circuits with jumper wires. (Job Sheet 2)
17. Check electrical circuits with a test light. (Job Sheet 3)

Objective Sheet

18. Check voltage in electrical/electronic circuits with a multimeter. (Job Sheet 4)

19. Check voltage drops in electrical/electronic circuits with a multimeter. (Job Sheet 5)

20. Check current flow in electrical/electronic circuits and components with a multimeter. (Job Sheet 6)

21. Check continuity and resistance in electrical/electronic circuits and components with a multimeter. (Job Sheet 7)

22. Find shorts, grounds, opens, and high resistance problems in electrical/electronic circuits. (Job Sheet 8)

23 Tin a soldering iron or gun. (Job Sheet 9)

24. Inspect, test, repair, and replace switches, connectors, terminals, and wires of electrical/electronic circuits. (Job Sheet 10)

25. Inspect, test, and replace fusible links, circuit breakers, and fuses. (Job Sheet 11)

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Information Sheet

Objective 1

Terms and definitions

a. **Calibrate**—To check and adjust a measuring instrument by comparing it with a standard.

b. **Continuity**—Refers to the circuit being continuous with no open.

c. **Functionality**—Capable of performing its function. In relation to a test instrument: the instrument works.

d. **Shunt/Current Clamp**—A device that can be used with a DVOM to increase the current measuring ability of the meter.

e. **Spiking**—A sudden, sometimes large, flow of voltage in a circuit; spiking can also refer to the sudden drastic change in the multimeter's display (an analog meter's needle will jump all the way to the right and DVOM's display will change to all 8s); spiking may damage the Multimeter or blow it's fuse.

Objective 2

Types of common circuits and their electrical characteristics

a. Series circuit

- Current flows from the power source through one path to all of the circuit elements.
- If one load is broken or damaged, all of the circuit is broken, and all other loads on that circuit will not operate, even though they are not damaged or broken.
- The sum of the voltage drops in a series circuit equals the applied voltage.
- The voltage drop varies directly with the resistance.
- The resistance in the series circuit equals the sum of individual resistance.

b. Parallel circuit

- Current flows through a number of paths (branches) to reach all of the circuit elements.
- If a load is broken or damaged, the circuit does not break as current can flow through another path to the other loads.
- Total current is the sum of the currents in the branches. The current in a branch varies inversely with the resistance of the branch.

- Total resistance of a parallel circuit is always less than the resistance of any branch.
- Total voltage drop is the same across all branches.
- The reciprocal of the total resistance equals the sum of the reciprocals of the parallel resistance.

c. Series-parallel circuit

- Current flows through one path (main line) to reach a number of paths (branches).
- If the current is damaged or broken in the main line, all current will stop to the other circuit elements.
- However, if the circuit is broken or damaged in one of the branch parts, it will not stop the current flowing through the other branches or the main line.
- To determine values of current, voltage and resistance in a series-parallel circuit, the circuit is broken down into an equivalent series circuit, identifying which are series components and which are parallel components.

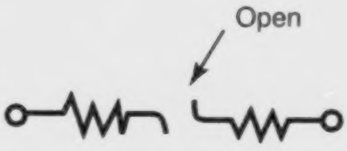
Objective 3

Common problems with electrical circuits (types, symptoms, causes)

Note: If connections and conductors are not protected from the elements (examples: cleaning fluid or road salt), they can corrode or rust. The corrosion or rust can cause an open, high resistance, or a short to ground or voltage. When the rust or corrosion is dry, the resistance is usually high enough not to affect the circuit. When wet, the resistance can be low enough to affect current flow.

a. Open

Figure 1



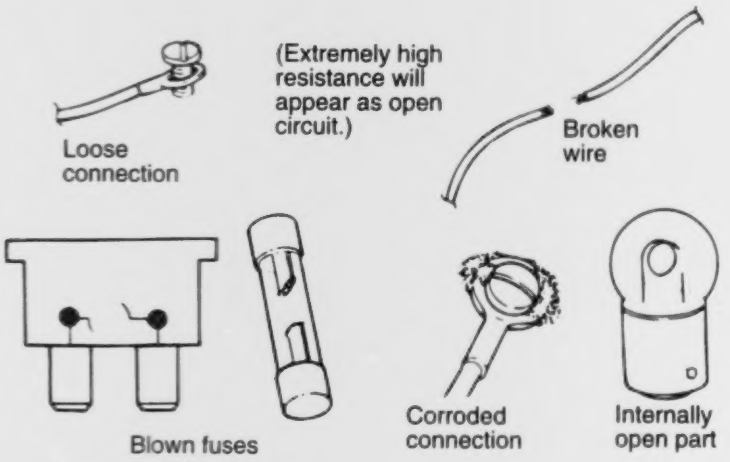
Description: The circuit is physically broken at some point, causing a gap across which the current cannot flow.

Note: Motion or vibration may cause the open in a circuit to close temporarily at times and operate normally. This is called an ***intermittent open***.

Symptom: Current does not flow in the circuit.

Note: If the open is in a series circuit, no current will flow in the entire circuit. If the open is on the main line of a parallel circuit or a series-parallel circuit, no current will flow in the entire circuit. If the open is on a branch circuit in a parallel or series-parallel circuit, current will not flow in the branch where the open is located, but current will flow in the other branches in the circuit.

Figure 2


Loose connection
(Extremely high resistance will appear as open circuit.)
Broken wire
Blown fuses
Corroded connection
Internally open part

Used with permission of DaimlerChrysler Corp.

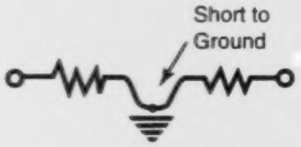
Frequent causes:

- broken, loose or corroded conductors
- blown fuses or tripped circuit breakers
- internally open loads or control devices

Note: Corrosion on a circuit device, for example, a terminal, makes the current pass through the resistance created by the corrosion in order to continue in the circuit. As the corrosion increases, the resistance increases until eventually it creates a gap across which the current cannot pass—an open.

b. **Short to Ground**

Figure 3


Short to Ground

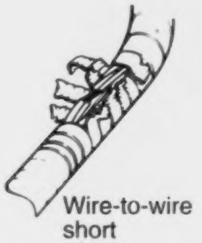
Description: An uninsulated part of a circuit touches the ground path, causing the current to flow into the ground path rather than continue in the circuit.

Note: Motion or vibration may cause a circuit with a short to ground to temporarily separate from the ground path at times and operate normally. This is called an *intermittent* short to ground.

Symptoms: No current flows in the circuit or the circuit cannot be turned off.

Note: If the short occurs before the load, the protection device on the circuit will blow or trip repeatedly. The extremely low resistance caused when the circuit grounds before reaching the load(s) results in very high current which blows or trips the protection device. If there is no protection device, the circuit may burn, possibly causing flame. If the short occurs after the load, but before the switch, the load cannot be turned off. If the short occurs after the load and the switch, there would be no apparent problem.

Figure 4



Used with permission of DaimlerChrysler Corp.

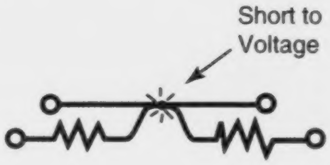
Causes:

- corroded conductor
- damaged insulation
- improper wiring

Note: In such cases, the insulation is often damaged by fasteners driven through wires, wires routed over sharp edges, and metal parts improperly placed to contact uninsulated portions of the wires.

c. Short to Voltage

Figure 5



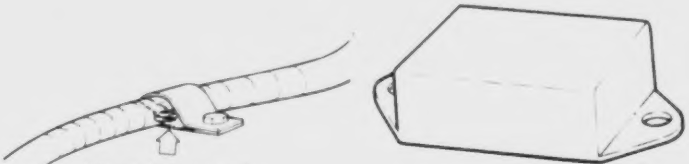
Description: Uninsulated sections of two circuits physically touching each other, allowing the voltage from one circuit to power the other.

Note: Because current always flows into the path containing the least amount of resistance, the circuit containing the most resistance will always power the circuit containing the least amount of resistance. Motion or vibration may cause circuits with a short to voltage to temporarily separate at times and operate normally. This is called an ***intermittent short*** to voltage.

Symptoms: Various and mysterious

Examples: Loads on a circuit may be inappropriately powered by an unknown source. Switches on one circuit may operate loads on another circuit. Fuses may blow out (as a result of the additional voltage to the circuit).

Figure 6



Short to ground

Internally shorted part
(often shows no sign
of failure)

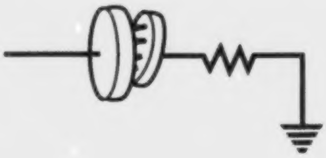
Used with permission of DaimlerChrysler Corp.

Frequent causes:

- corroded connection or conductor
- damaged insulation
- improper wiring

d. **High Resistance**

Figure 7

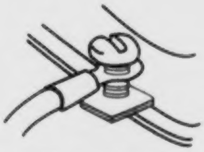


Description: An unintended circumstance increases resistance in the circuit.

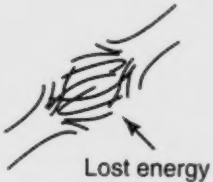
Symptom(s): Current in the circuit is at a lower level than normal.

Examples: dim lights, slow motor operation

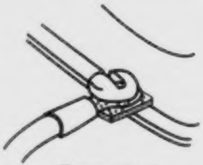
Figure 8



Poor or loose connections



Lost energy through heat damaged wires



Corroded connections

Frequent causes:

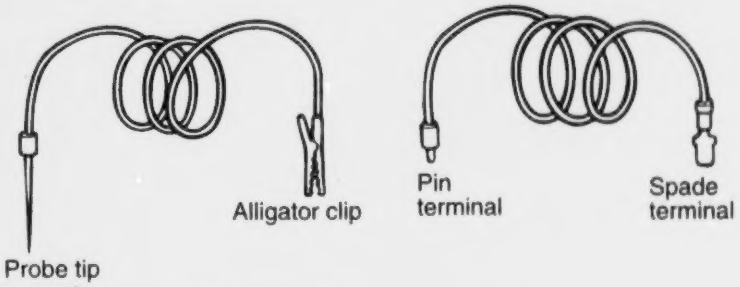
- dirt or corrosion on connectors or terminals
- terminals crimped to insulation instead of conductor
- loose conductors
- bent or loose terminals
- damaged wires
- improper wiring
- broken connector lock

Objective 4

Types of electrical diagnostic instruments (names and illustrations, usage, calibrated vs. tested requirements)

a. Jumper wires

Figure 9



Used with permission of Ford Motor Co.

Description of use: Use to bypass part of a circuit.

Problems that can be diagnosed:

- shorts
- opens

Rules for handling:

- Never connect a jumper wire across a battery. This could cause the battery to explode.
- Always use the correct mating terminals on jumpers when testing a circuit terminal. This will prevent damage to the terminal and allow you to obtain a truer reading.
- It is highly recommended that you only use jumper wires containing a circuit breaker or fuse to prevent personal injury and damage to the circuit.
- Never use a jumper wire to bypass a load unless required by a specific procedure.

Note: Bypassing the load device eliminates substantial resistance from the circuit, resulting in excessive current which will overheat the circuit and/or trigger the circuit's protective device.

- Do not use a jumper wire without a fuse to bypass a protective device. Circuit damage may result.
- Be careful when handling the end of a jumper wire located away from the power source (the positive side) so that you don't accidentally touch a ground path and cause a short in the circuit you are testing.

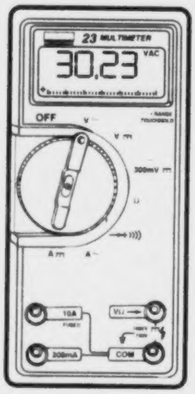
Note: Some tool manufacturers make jumper wire kits containing tips with different terminals that will properly mate with the terminals on the vehicle. At times, you may have to design them yourself because they won't be available. Remember, if a connection doesn't fit properly, it will add resistance to the circuit resulting in false diagnostic readings. This might lead you to perform unnecessary repairs. Always use the right diagnostic tools and make sure they are functioning properly before performing diagnostic checks.

Test for functionality before use? Yes

Calibrate before use? No

b. **Digital Multimeter**

Figure 10



Used with permission of DaimlerChrysler Corp.

Description of use: Used to detect and measure current, voltage, frequency, or resistance in a circuit or circuit device.

Problems that can be diagnosed:

- identify voltage source
- opens
- shorts to ground
- shorts to voltage
- amperage usage
- resistance problems
- frequency output problems

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Rules for handling:

- Always follow manufacturer's instructions when operating a multimeter.
- Always use the proper terminal ends on test leads to obtain correct readings and not damage the terminal.
- Handle multimeters carefully. They can be easily damaged.
- If multimeter comes with a protective case, use multimeter with the case attached.
- When testing for frequency, never connect the multimeter to a circuit or component connected to a power source.
- When using the ammeter function, never bypass a load with a multimeter.
- When using the ohmmeter function, never connect the multimeter to a circuit or component connected to a power source.

Test for functionality before use? Yes

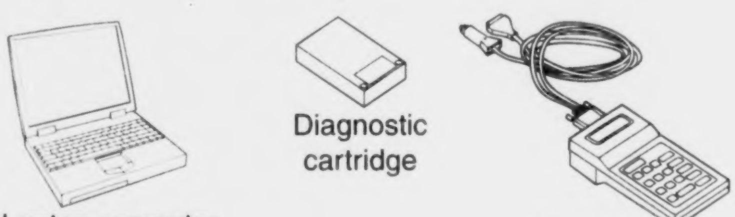
Calibrate before use? Yes

c. Scan Tool

Description of use: Connects to the vehicle's computer and displays diagnostic information to the technician.

Note: A scan tool can be a laptop computer loaded with the appropriate software, or a mini-computer loaded with a diagnostic cartridge.

Figure 11



Laptop computer

Diagnostic cartridge

Scan tool

Problems that can be diagnosed:

- opens
- shorts to ground
- shorts to voltage
- problems with the vehicle's computer

Rules for handling:

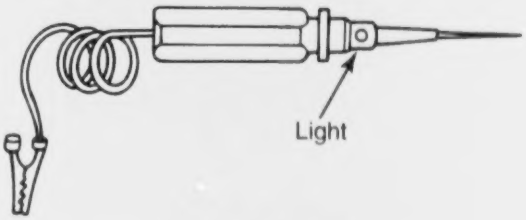
- Always follow manufacturer's instructions when operating a multimeter.
- Handle scan tools carefully. They can be easily damaged.
- Always refer to the service manual when interpreting diagnostic codes and information.
- Always unplug the scan tool from the power source before changing the cartridge unless otherwise stated in the operator's manual.

Test for functionality before use? Yes

Calibrate before use? No

d. 12-Volt Test Light

Figure 12



Used with permission of DaimlerChrysler Corp.

Description of use: Used to check for the presence of voltage or a ground in a circuit.

Problems that can be diagnosed:

- opens
- shorts

Rules for handling:

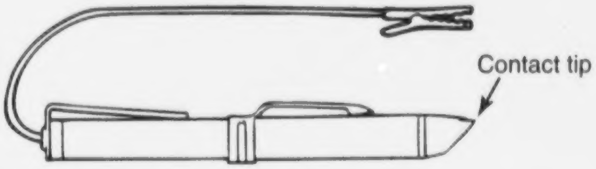
- Be careful of the sharp tip of the probe; injury may result.
- Do not probe the insulation of any wire or device.
- Do not use a test light in a circuit containing electronic circuit devices or a computer unless the vehicle's service manual specifically calls for its use.

Test for functionality before use? Yes

Calibrate before use? No

e. Self-powered Test Light

Figure 13



Used with permission of Ford Motor Co.

Description of use: Used to check for continuity in a circuit or circuit device that is not connected to a power source.

Problems that can be diagnosed:

- opens
- shorts to ground

Rules for handling:

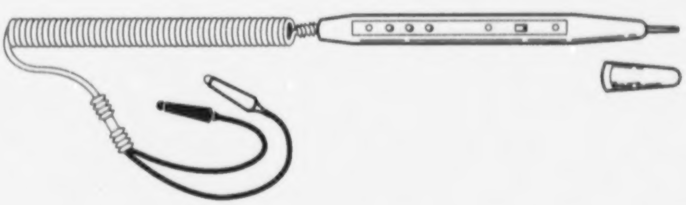
- Be careful of the sharp tip of the probe. Injury may result.
- Do not connect a self-powered test light to a circuit or circuit device connected to voltage. The bulb in the test light will be damaged.
- Circuits or circuit devices with too much resistance will not light the lamp of a self-powered test light because it uses low voltage.
- Do not check circuits and components that operate on milliamperes (computer circuits) with a self-powered test light. The current of the test light will damage the circuit or components.

Test for functionality before use? Yes

Calibrate before use? No

f. Logic Probe

Figure 14



Description of use: Used to check continuity in circuits transmitting digital signals to and from computers.

Problems that can be diagnosed:

- opens
- inappropriate voltage level
- existence of digital signals in the circuit
- existence of a ground

Rules for handling:

- Be careful of the sharp tip of the probe. Injury may result.
- Always follow manufacturer's instructions when connecting the logic probe.

Test for functionality before use? Yes

Calibrate before use? No

g. Digital Storage Oscilliscope (DSO)

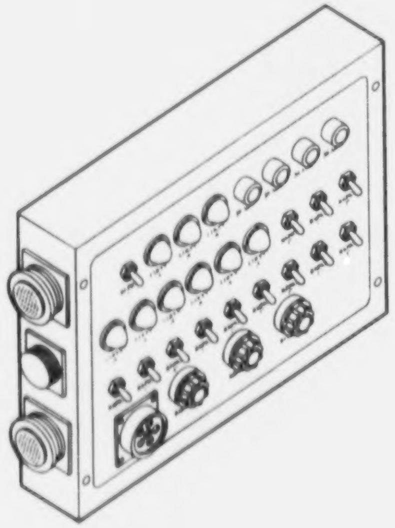
Description of use: Designed to save, print, measure, and compare the waveform to other waveforms of voltage changes in a circuit over time.

Rules of use: Always follow manufacturer's instructions as not all scopes connect to the circuit in the same way.

Note: The DSO differs from the scope because it can save and print the waveform of an electrical current. The scope can only trace a live circuit. It can not freeze the trace for viewing. The DSO allows the trace to be held on its screen, saved to memory, moved around on the screen, and downloaded to a personal computer. The ability to save and print a waveform makes it an invaluable tool to the technician for finding non-repetitive or intermittent glitches that can be hard to detect.

h. **Vehicle Interface Module**

Figure 15



Description of use: Used to isolate the piece of equipment being tested from the vehicle. The equipment can be operated without vehicle controls while still mounted in the vehicle.

Problems that can be diagnosed:

- shorts to ground
- shorts to voltage
- opens

Rules for handling:

- Always follow the manufacturer's instructions for the vehicle, the equipment being tested, and the vehicle interface module.
- Always refer to the service manual when interpreting diagnostic/fault codes.
- Always unplug the module's power source before connecting or disconnecting the module from the vehicle or equipment.

Test for functionality before use? Yes

Calibrate before use? Yes

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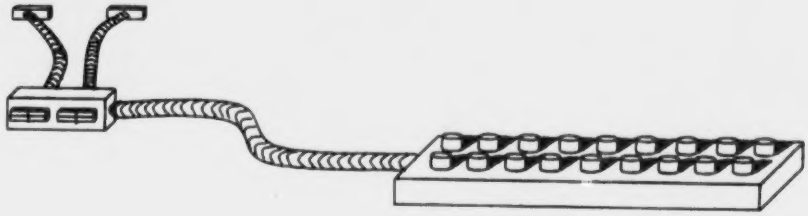
Note: The Vehicle Interface Module (VIM) is a great diagnostic tool. When a vehicle has an electrical problem that can't be found by other means, you can use the VIM to isolate areas of the vehicle to determine whether it's the piece of equipment or the control that is malfunctioning.

i. Harness Pinout Box/Breakout Box

Figure 16



Description of use: Designed to be connected inline of the harness having a problem. Individual circuits can be tested while current is flowing through the circuit.

Problems that can be diagnosed:

- shorts to ground
- shorts to voltage
- opens

Rules for handling:

- Always follow the manufacturer's instructions for the vehicle or equipment being tested.
- Always refer to the service manual when interpreting diagnostic codes.
- Take care not to damage the terminals or allow them to corrode.

Test for functionality before use? Yes

Calibrate before use? No

Note: Before using this diagnostic tool, familiarize yourself with what the circuit is supposed to be doing as stated in the service manual, and keep the service manual nearby so you will have a reference for comparing readings.

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Objective 5

Steps in electrical troubleshooting

- **Listen**—Pay attention to the client as they explain how the piece of equipment is malfunctioning. If you are familiar with the piece of equipment and its circuits, the symptoms may tell you where the problem lies. Pose questions in your mind as you listen so you can adequately question the client about the problem(s).

- **Verify problem**—Check out the symptoms and problem as described by the client. Operate the equipment to try to duplicate the problem. If you can't duplicate the problem, then it may be intermittent.

  Note: Intermittent problems are the hardest to solve because they are hard to verify with test equipment. Most troubleshooting charts do not address intermittent problems. This is why listening to the client is so important.

- **Visualize**—Think of how the current flows through the circuit, each connection, and each component.

  Note: Locate the appropriate service manual. Although different manufacturers use the same type of electronic equipment, they may locate them in different places or wire them differently. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

- **Narrow**—Use the manual and wiring diagrams to see how the system is designed and how it should perform. Compare the results found in the "verify" step with how the equipment was designed to operate. Analyze the number of possibilities for the problem and eliminate problem sources by using knowledge of the specific system and the basic rules of electricity.

- **Test**—Determine and perform the test that is needed, with the proper tools, to locate the problem(s).

- **Repair**—Replace a bad circuit device, solder and heat shrink a broken wire, repair or replace a broken connector, replace a bad terminal, and/or wire the circuit correctly.

- **Verify repair**—Make sure the circuit is operating correctly. Test drive the vehicle or operate the equipment in the same way the client operates it and the same way you operated it to "verify" the problem. If the problem does not return, the job is complete. If the problem returns, start the process over by talking to the client and asking more questions.

Information Sheet

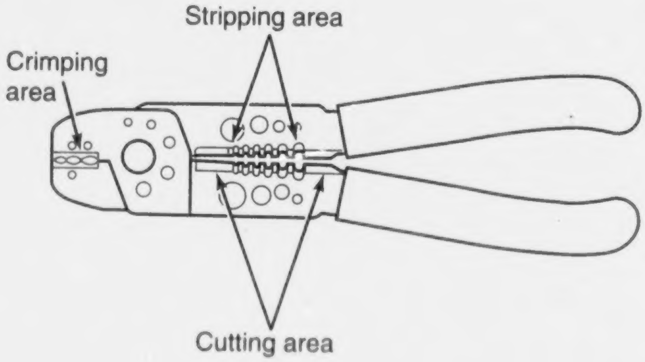
Objective 6

Steps in soldering

Note: Electrical circuits can often be repaired by splicing and soldering electrical wires.

a. Strip wire (remove its insulation) using an electrician's stripper-crimper. Use the proper hole for the gauge of wire you are stripping to prevent nicks and cuts.

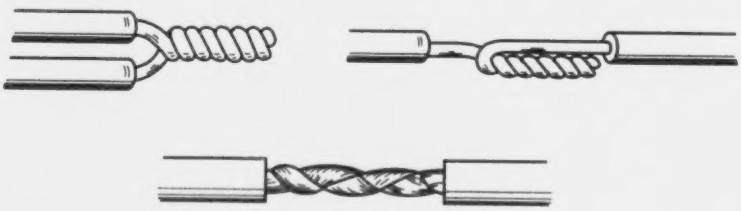
Figure 17



b. Clean the exposed wiring using rosin-type cleaning-flux solution (**not acid flux!**) to ensure a good electrical connection.

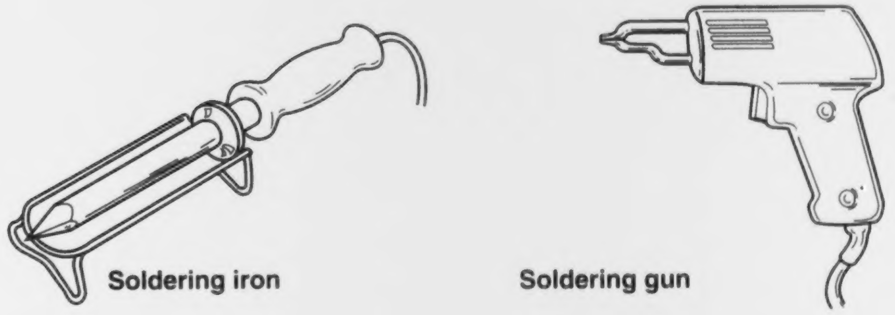
c. Twist or splice the exposed wiring securely, but gently.

Figure 18



d. Put on safety glasses and then prepare soldering iron or soldering gun by cleaning and tinning the tip with a thin coat of rosin-core solder.

Figure 19



Soldering iron **Soldering gun**

e. Solder exposed pieces of spliced wiring using soldering iron or gun and rosin-core solder. **Acid-base colder should not be used in electrical circuits.**

f. Allow solder to cool and then test connection to make sure it is secure.

g. Reinsulate the connection using heat-shrink insulation and a heat gun.

Objective 7

Guidelines for soldering

a. Always wear protection while soldering. Hot solder can cause serious eye injury.

b. Hold the tip of the soldering iron or gun so that a large area of the tip contacts the wiring until the wiring gets hot enough to melt the solder. Enough heat must be generated so that the solder flows freely as a liquid and does not become pasty or mushy.

c. Move the solder along the wiring to allow the solder to cover the length of the splice.

d. Use only enough solder to flow between the wiring strands to form a good bond. Do not build up solder on the surface of the wiring.

e. A well-soldered connection (joint) will appear smooth and shiny, with no apparent holes. A poorly soldered connection—a connection soldered with heat insufficient to properly heat the wire, called a *cold joint*— will have a dull, rough appearance.

f. Solder connections must meet two requirements:

1) Good physical connection

2) Good electrical connection

Student Supplement 1—Values, Prefixes, and Symbols

The *metric system*, a means of standardization, is based on the number 10. Numbers with 12 or more zeros in them can be cumbersome, and both space- and time-consuming. Therefore, a system of prefixes makes calculations easier. These prefixes, together with their associated symbols and values are:

Term	Symbol	Value
pico	p	1/1,000,000,000,000
nano	n	1/1,000,000,000
micro	μ	1/1,000,000
milli	m	1/1,000
kilo	k	1,000
mega	M	1,000,000

Notice that prefixes for numbers greater than one are symbolized by capital letters, but symbols for prefixes of less than one are lower case letters. Also, note that the Greek symbol μ (pronounced "mu") is used as the symbol for micro, instead of "m", to avoid confusion with the symbol used for the prefix "milli."

As shown in the chart above: to convert any value to mega, move the decimal point six places to the left; to convert any value to kilo, move the decimal point three places to the left; to convert any value to milli, move the decimal point three places to the right; to convert any value to micro, move the decimal point six places to the right.

The following list provides some examples of how prefixes would be used in conjunction with common circuit variables. The abbreviation provided with each example is the way that value would actually be written on schematics or other technical information.

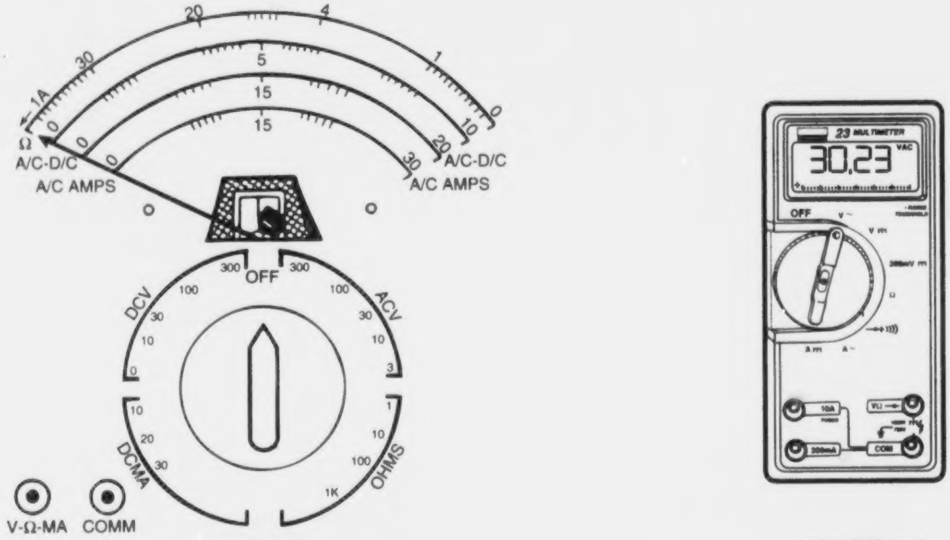
Term	Value	Abbreviation
1 picvolt	0.00000000001 volt	1pV
15 nanoamps	0.000000015 amp	15nA
200 microvolts	0.0002v	200μV
78 milliamps	0.078 amp	78mA
3 megawatts	3,000,000 watts	3MW

Student Supplement 2—Multimeters

Four basic test meters, a voltmeter, ammeter, ohmmeter, and frequency meter measure voltage, current, resistance, and Hertz. A Multimeter combines these test meters into a single case or console. Diagnosing problems involving electricity is almost totally dependent upon being able to use a Multimeter. The Multimeter is the most versatile tool used in diagnosing engine performance and electrical systems.

A Multimeter precisely measures and accurately displays measurements of current, voltage, resistance, and frequency. Multimeters are available with either *analog* (commonly called a VOM) or *digital* (commonly called a DVOM) displays. (Figure 1)

Figure 1



VOM

DVOM

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Analog meters (meters that have a pointer or needle that moves across a numbered dial or scale) have low internal resistance (impedance) which allows a large amount of current to flow through circuits and should **not** be used on delicate electronic devices. Analog meters are limited to testing circuits where current draw through the system is not critical, or the tuning of some circuits that require monitoring of the voltages that change with adjustments are made during alignment procedures. These slow changes are easier to see on the rising and falling pointer-type display of an analog meter than they are to interpret in the changing digits of a digital-meter display. Testing the starting system is a good example of when an analog meter would be appropriate.

Student Supplement 2

Today most technicians use electronic meters that provide a digital readout. Most digital meters have a high internal resistance, usually at least 10 megohms. Digital metered voltage for resistance tests is well below 5 volts, reducing the risk of damaging sensitive components and delicate computer circuits. The readouts on digital multimeters are shown on an LED (light-emitting diode) display or LCD (liquid-Crystal) display. The digital meter is available in two different models: switchable range-selector or an auto range feature, in which the appropriate scale is automatically selected by the meter. Usually there are several test ranges provided for each function of the multimeter. It is important to be familiar with the prefix being displayed before the reading or range. Ohmmeter scales are expressed as a multiple of tens or use the prefix K or M. Digital meters usually display the measurement with a decimal point.

Correct polarity is indicated by a positive (+) sign displayed ahead of the voltage value. Digital multimeters often indicate reverse polarity (test leads connected backwards) by displaying a minus (-) sign ahead of the voltage value. When measuring current or voltage, it is important to observe polarity. In other words, the red lead should be connected to the positive side of the component being measured, and the black lead should be connected to the negative side. Polarity is not important when measuring resistance except in the case of some solid state devices such as diodes.

Note: Always check the service manual to make sure you're using the right type of multimeter, and don't try to use a multimeter without reading and understanding the operator's manual.

Student Supplement 3—Stripping, Splicing, Crimping, and Soldering

Stripping

Before soldering or splicing insulated wire, some of the insulation must be removed to expose the bare wire conductor. When stripping the insulation from wires or fusible links, use an approved set of wire strippers to prevent damage to the wire conductor. Be sure to match the gauge of the wire to the proper stripping hole on the plier. Sometimes it's difficult to determine the gauge of the wire. If the gauge is not printed on the insulation, refer to the wiring diagram for that particular piece of electrical equipment. Don't rely solely on color, because over time colors can fade or the wire may have gotten singed or dirty.

How much insulation should be stripped from the wire depends on where the wire will be placed, or what you are intending to do with it. The best course of action is to measure the amount on the particular terminal or pin you are using.

After stripping the insulation off the wire, do not twist the wire strands because they will overlap and not run parallel with the terminal.

Splicing

Wire splicing is a process that joins two or more wires together to form an electrical connection. Cold splicing (twisting the wires together using a solderless splice) is not recommended for most repairs; soldering is the preferred method for most wire repairs. When replacing or repairing a wire, it is important that the correct size or gauge be used. Wire length is as important as wire gauge. As the length of the wire conductor increases, so does resistance. The wires must be held securely in place to prevent damage.

Crimping

There are two types of crimping—open-barrel and closed barrel (Figure 1). Pin contacts installed in connector bodies are of the open-barrel type. Most terminals are of the closed-barrel type. Terminals and pin and socket contacts require two crimps. The first crimp secures the bare wire strands in the throat of the barrel. The second crimp secures the end of the insulation in the insulation barrel.

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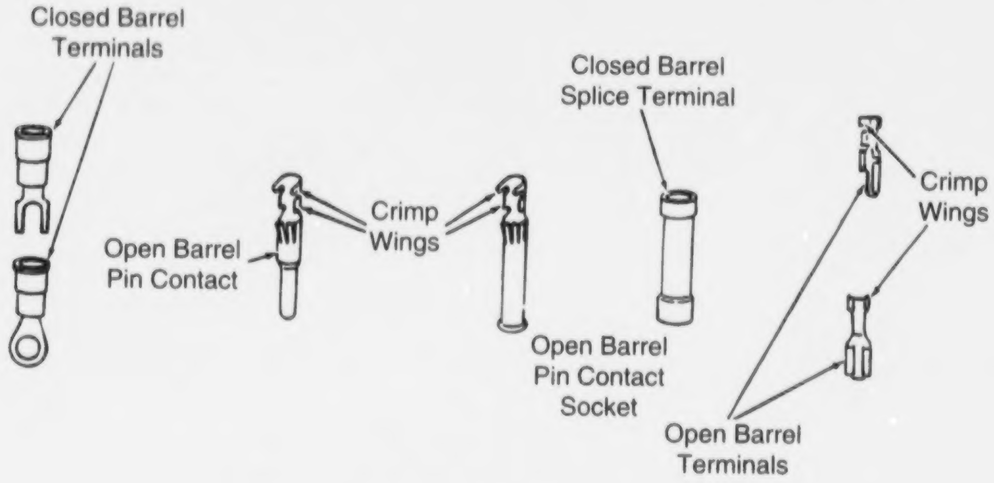
Figure 1—Closed- and open-barrel terminals and pin contacts


Closed Barrel Terminals
Closed Barrel Splice Terminal
Crimp Wings
Open Barrel Pin Contact
Crimp Wings
Open Barrel Pin Contact Socket
Open Barrel Terminals

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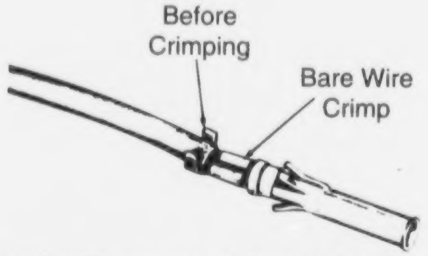
Open-Barrel Crimping

Open-barrel crimping of pin and socket contacts is a two-step process. First, the bare wire must be crimped inside the barrel of the contact. Insert a stripped wire into the wire barrel. Make sure you've stripped enough wire by placing the wire so that the end of the insulation fits just inside the first crimp wing. The bare wire strand should extend into throat of the barrel. Position the pin or socket in the crimping tool with the crimp wings centered. Crimp the bare wire strand (Figure 2).

Figure 2—Pin socket after bare wire crimp


Before Crimping
Bare Wire Crimp

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Now that you've crimped the bare wire strand, you have to crimp the end of the insulation. Your completed job should look like Figure 3.

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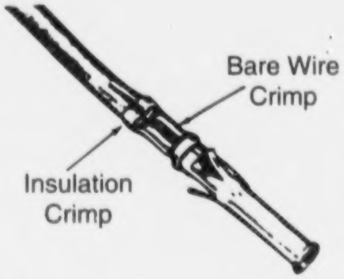
Figure 3—Pin socket after both crimps


Bare Wire
Crimp
Insulation
Crimp

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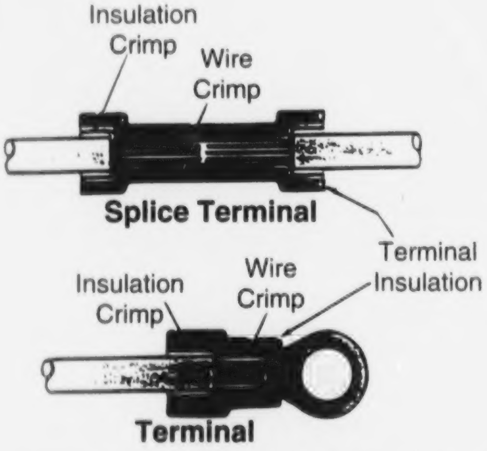
Note: For Weather Pack™ connectors, a cable seal must be placed onto the wire prior to placing the wire into the contact for crimping. The cable seal will be crimped onto the wire when you make the insulation crimp.

Closed-Barrel Crimping

Closed-barrel crimping is also a two-step process and follows the same procedures as open-barrel crimping. The major difference lies in the type of connector(s) associated with each process. While open-barrel crimping is normally used with pin and socket contacts, closed-barrel crimping is normally associated with terminals and splices.

Figure 4—Closed-Barrel Splice and Terminal


Insulation
Crimp
Wire
Crimp
Splice Terminal
Terminal
Insulation
Insulation
Crimp
Wire
Crimp
Terminal

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Student Supplement 3

Soldering

There are two main reasons to solder electrical connections. One is to maintain a gas-tight seal, and the other is to make-up for any mistakes you might have made during the crimping process.

When soldering electrical connections, always use a low wattage (about 30-watts) soldering iron and rosin core solder. **Never use acid core rosin because corrosion is likely to occur**. Clean the wire ends and/or connections. Solder does not stick to paint, wax, grease, or melted insulation. It is important to note that the art of soldering requires heating the connection, not the solder, with the soldering tool. Always use rosin core solder when making electrical repairs. Heat from the soldering iron should be applied underneath, and solder should be applied to the top. With the hot iron on the connection, apply solder and allow it to flow through and around the connection before removing the iron. Don't apply too much solder or move the connection before it cools. Inspect the joint after it cools. The joint should be shiny; dull appearance may indicate an improper or cold solder joint.

If the soldering tip is battered or rough, square it and smooth it with a file. Be careful to remove only enough material to smooth the soldering surfaces and sharpen the tip. After you have filed the tip clean, touch the soldering faces to a block of sal ammonia or rosin and then touch the tip to a bar or piece of wire solder. The solder will melt and spread over the soldering surfaces.

Student Supplement 4—Wire Connectors

Increases in the use of electrical and electronic equipment and monitoring systems have brought about a need for more and different types of connectors in all shapes and sizes. These connectors require increased maintenance because they protect splices in severe conditions such as extreme heat and cold, moisture, dirt, dust, and excessive vibration.

Current Flow and Resistance in Connectors

Connectors pass current from one set of wires to another and are made-up of two half connectors. One half of the connector houses the male pin contacts and the other half contains the female socket contacts. These pins and sockets are merely extensions of the wires they're connected to. The integrity of the circuit depends on the type of connector used and the quality of the repair made to the connector. Loose and/or corroded connectors can lead to increased resistance, which results in voltage drops that can affect the circuit and its load.

Pin and socket contacts look and feel as though they have smooth surfaces, but under a microscope the surfaces look like they have peaks and valleys. This is called *asperity*. As a result of asperity, a very small percentage of the actual surface of the pin and socket contact each other. This causes increased resistance at the contact point. Resistance can be minimized at the connector, but this is dependent on surface finish, the kind of metal used, and contact pressure. Copper is a hard metal with high conductivity, but has low resistance. Tin has high resistance but is a soft metal. Since low resistance is the goal, copper contacts are plated with tin. When pins and sockets are coated with tin and connected together, the soft characteristics of tin allows the contacts to "smooth out" some of the peaks and valleys thus reducing resistance.

Common Types of Connectors

There are several types of connectors because each type is used for a different application. Although each type connector is different, there are three characteristics they all have in common.

- They have locking mechanisms so they can't inadvertently become disconnected.
- Pin contacts can be removed or replaced when they become broken or bent.
- Both halves either have an alignment guide, or the pins are arranged so that the two halves cannot be connected incorrectly.

Although there are several different types of connectors, in this supplement we'll discuss the seven connectors you'll see most often in a diesel shop.

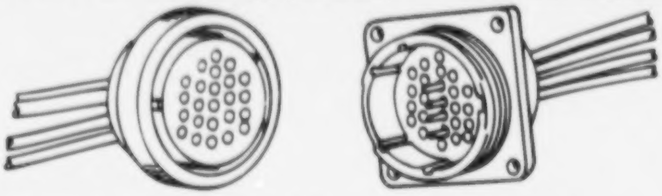
Note: Contacts can either be crimped or soldered to wire leads.

Student Supplement 4

Figure 1

Circular Plastic Connector with Pin-Type Contacts

Connector:



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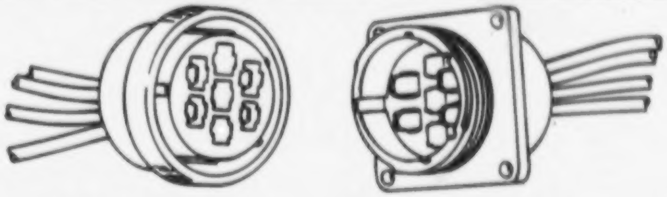
Characteristics:
This connector is available in a variety of configurations. The figure shows a connector that will accommodate 24 contacts but uses only four. You will only need four female socket contacts for this particular configuration. The connector will only mate in one way so you have to make sure the socket contacts align with where the pin contacts are placed. To mate the connector halves, align the guide keys, push the two halves together, and then turn the knurled connector half clockwise to engage the locking flange.

Installing and removing pin and socket contacts:
Both male and female contacts are installed by pushing them far enough through the back of the connector to engage the locking flange on the pin. To remove the pin contacts, insert the special extracting tool over the pin contact in the connector body (cavity) making sure the tool bottoms out in the connector so that the locking flanges on the contact will be depressed. Then pull the wire and pin contact out through the back.

Figure 2

Circular Plastic Connector With Blade-Type Contacts

Connector



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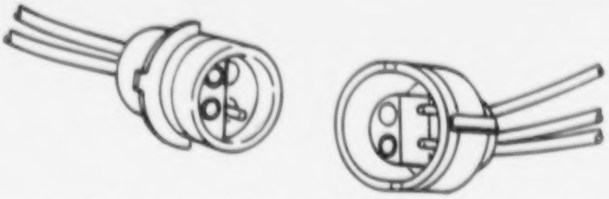
Characteristics:
This connector is available in a variety of configurations. The figure shows a connector that will accommodate seven contacts although fewer than seven contacts can be used. You will need seven female socket contacts for this particular configuration. The connector will only mate in one way so you have to make sure the socket contacts align with where the pin contacts are placed. To mate the connector halves, align the guide keys, push the two halves together, and then turn the knurled connector half clockwise to engage the locking flange.

Installing and removing pin and socket contacts:
Both male and female contacts are installed by pushing them far enough through the back of the connector to engage the locking flange on the pin. To remove blade contacts, insert the special extracting tool over the pin contact in the connector body (cavity) making sure the tool bottoms out in the connector so that the locking flanges on the contact will be depressed. Then pull the wire and pin contact out through the back.

Figure 3

Sure-Seal™ Connector

Connector



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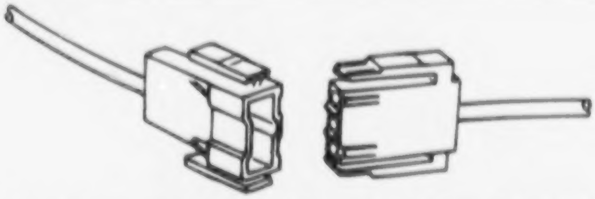
Characteristics:
Each mating half contains both male and female contacts. This connector does not use guides for proper mating. Instead, the connector bodies are molded and will not align incorrectly.

Installing and removing pin and socket contacts:
This connector requires two special tools for installing the pin contacts. One is the insertion tool used to install the pin contacts and the other is a holding plate used to steady the connector while installing the pin contacts. Contacts are inserted into the connector through the back with the wire positioned inside the tip of the contact insertion tool. To remove a contact, pull it out by grasping the wire. If this doesn't work, use a small screwdriver to press the contact from the housing.

Figure 4

Metrimate™ Connector

Connector



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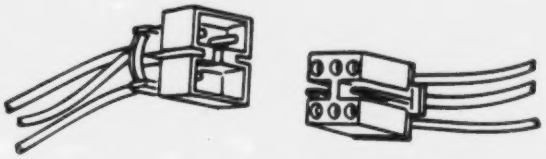
Characteristics:
This connector has provisions for three pin and socket contacts. The connector halves can only be mated in one way. The locking mechanism consists of clips and engages when the two halves are mated together. To separate the two halves, the clips must be depressed while pulling them apart.

Installing and removing pin and socket contacts:
Both male and female contacts are installed by pushing them far enough through the back of the connector to engage the locking flange on the pin. To remove pin contacts, insert the special extracting tool over the pin contact in the connector body (cavity) making sure the tool bottoms out in the connector so that the locking flanges on the contact will be depressed. Then pull the wire and pin contact out through the back.

Figure 5

Mate-'n-Lok™ Connector

Connector



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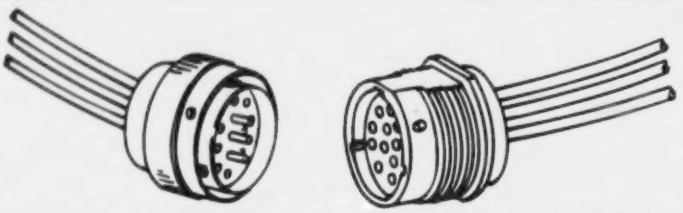
Characteristics:
This connector has provisions for six contacts although fewer than six can be used. The connector halves can only be mated in one way. The locking mechanism consists of clips and engages when the two halves are mated together. To separate the two halves, the clips must be depressed while pulling them apart.

Installing and removing pin and socket contacts:
Both male and female contacts are installed by pushing them far enough through the back of the connector to engage the locking flange on the pin. To remove pin contacts, insert the special extracting tool over the pin contact in the connector body (cavity) making sure the tool bottoms out in the connector so that the locking flanges on the contact will be depressed. Then pull the wire and pin contact out through the back.

Figure 6

Deutsch™ Connector

Connector



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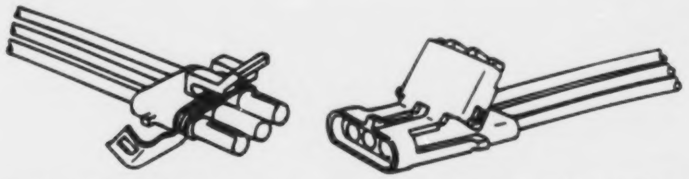
Characteristics:
This circular connector is available in a variety of configurations, and is available in different sizes to accommodate varying numbers of pin contacts. Some models allow two different pin sizes. Contact holes have soft rubber around them to seal out contaminants. To mate the connector halves, align the guide keys, push the two halves together, and then turn the knurled connector half clockwise to enage the locking flange.

Installing and removing pin and socket contacts:
Both male and female contacts are installed by pushing them far enough through the back of the connector to engage the locking flange on the pin. The remove contacts, depress the locking flange and pull the contact out from the back of the connector (this requires a special tool). The difference between the circulate type connectors and this one is that the tool is inserted into the wire side of the connector.

Figure 7

Weather Pack™ Connector

Connector



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Characteristics:
This connector comes in a variety of configurations. The male connector half comes with a molded silicone seal attached. This creates a seal against contaminants when the two halves are mated together. Each wire is provided with a cable seal to keep contaminants from entering the connector at the wire leads. Cavity plugs are inserted into vacant holes to seal out contaminants. The connector halves can only be mated in one way. The locking mechansim consists of clips and engages when the two halves are mated together. To separate the two halves, the clips must be depressed while pulling them apart.

Installing and removing pin and socket contacts:
Install pin contacts through the rear of the connector making sure the cable seal is flush with the connector body. To remove pin contacts, insert the special extracting tool over the pin contact in the connector body (cavity) making sure the tool bottoms out in the connector so that the locking flanges on hte holiday will be depressed. Then pull the wire and pin contct out through the back.

Objective 8

Assignment Sheet 1—Identify Types of Circuits and Circuit Devices on a Circuit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 12 of the 15 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Writing Mathematics Critical Thinking

Introduction

The electrical troubleshooting process assumes that you understand Ohm's Law, that you can calculate, and that you know how to use the various diagnostic instruments. Before you can test the circuits and circuit devices, however, you must first know which circuit devices are on the circuit. Because the application of Ohm's Law changes according to the type of circuit, you must also know what type of circuit you'll be testing.

The client with a headlight problem doesn't know, or even care, if there's a short or an intermittent open or a high resistance problem. He probably can't tell you which Ohm's Law formula to use. Most likely, the client can't even tell you whether you'll be testing a series-parallel circuit with three devices on it or a parallel circuit with 33 devices. You must be able to locate the applicable circuit drawing and identify the type of circuit and circuit devices so that you can perform the applicable tests.

In this Assignment Sheet you'll be presented with some typical situations and appropriate sample circuit drawings and asked to correctly identify the circuit type and all the circuit devices on that circuit. This will prepare you for later assignments that will have you identify points on a circuit that require testing and applying Ohm's Law to perform calculations. All these assignments come together to help enhance your diagnostic skills.

Assignment Sheet 1

Figure 1, Wiring Diagram A

Simplified Headlight Circuit

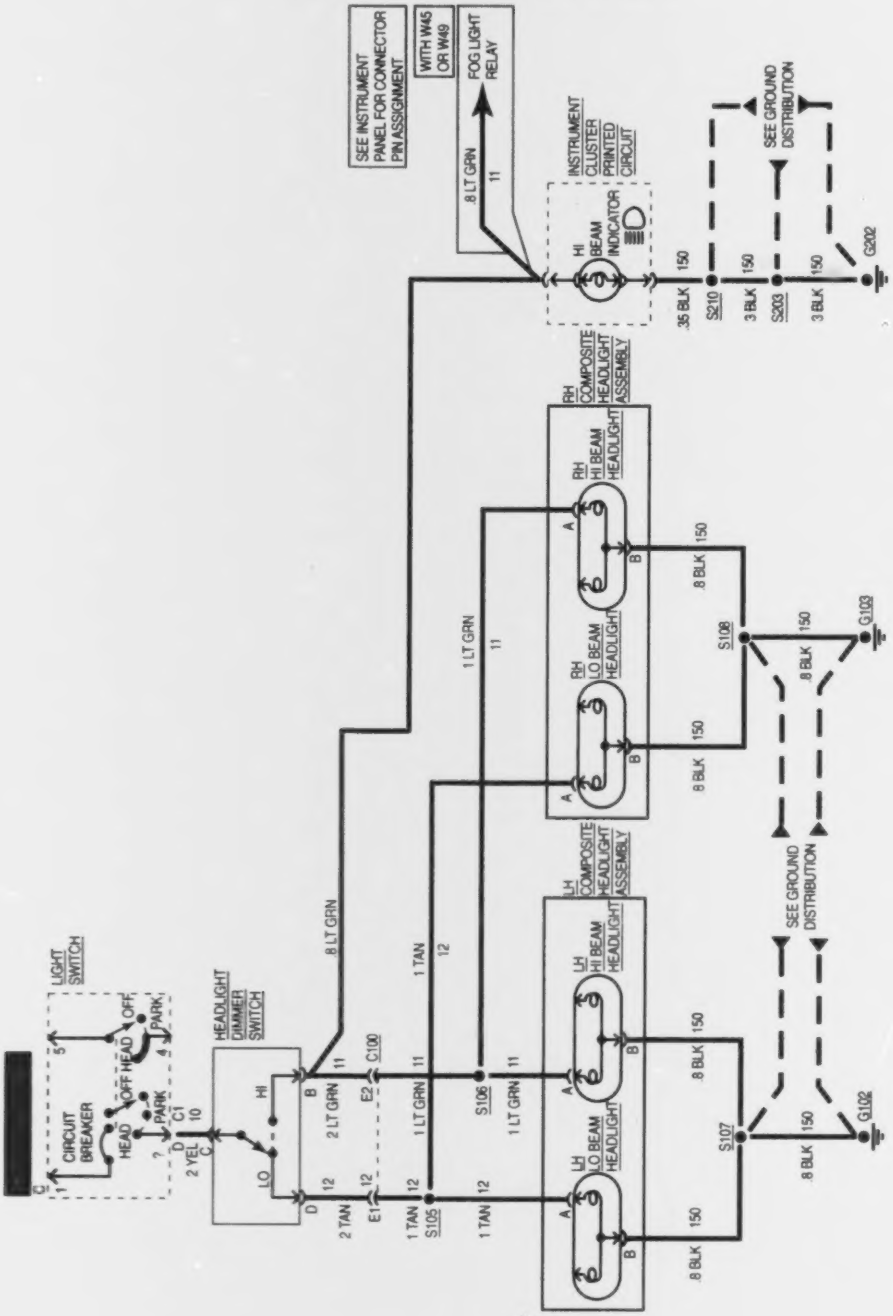
SEE INSTRUMENT PANEL FOR CONNECTOR PIN ASSIGNMENT
WITH W45 OR W49
FOG LIGHT RELAY
.8 LT GRN
11
INSTRUMENT CLUSTER PRINTED CIRCUIT
HI BEAM INDICATOR
.35 BLK
150
S210
3 BLK
150
S203
3 BLK
150
G202
SEE GROUND DISTRIBUTION
RH COMPOSITE HEADLIGHT ASSEMBLY
RH HI BEAM HEADLIGHT
RH LO BEAM HEADLIGHT
A
B
.8 BLK
150
S108
G103
1 LT GRN
11
LH COMPOSITE HEADLIGHT ASSEMBLY
LH HI BEAM HEADLIGHT
LH LO BEAM HEADLIGHT
.8 BLK
150
S107
G102
.8 LT GRN
1 TAN
12
LIGHT SWITCH
CIRCUIT BREAKER
HEAD
OFF
PARK
5
4
C1
10
D
C
2 YEL
HEADLIGHT DIMMER SWITCH
HI
LO
B
D
2 LT GRN
2 TAN
E2
E1
C100
S106
S105
1 TAN
1 LT GRN

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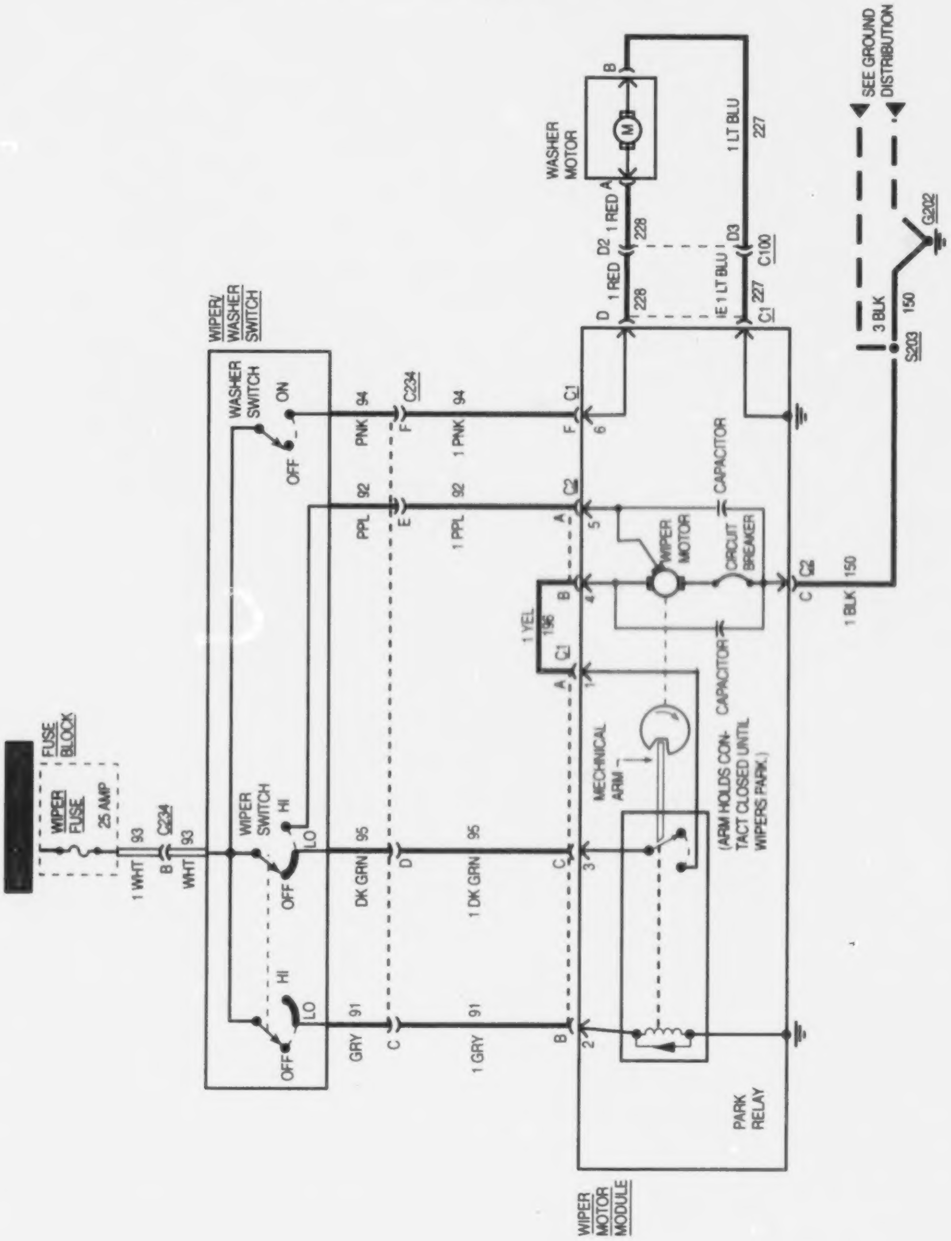
Figure 2, Wiring Diagram B

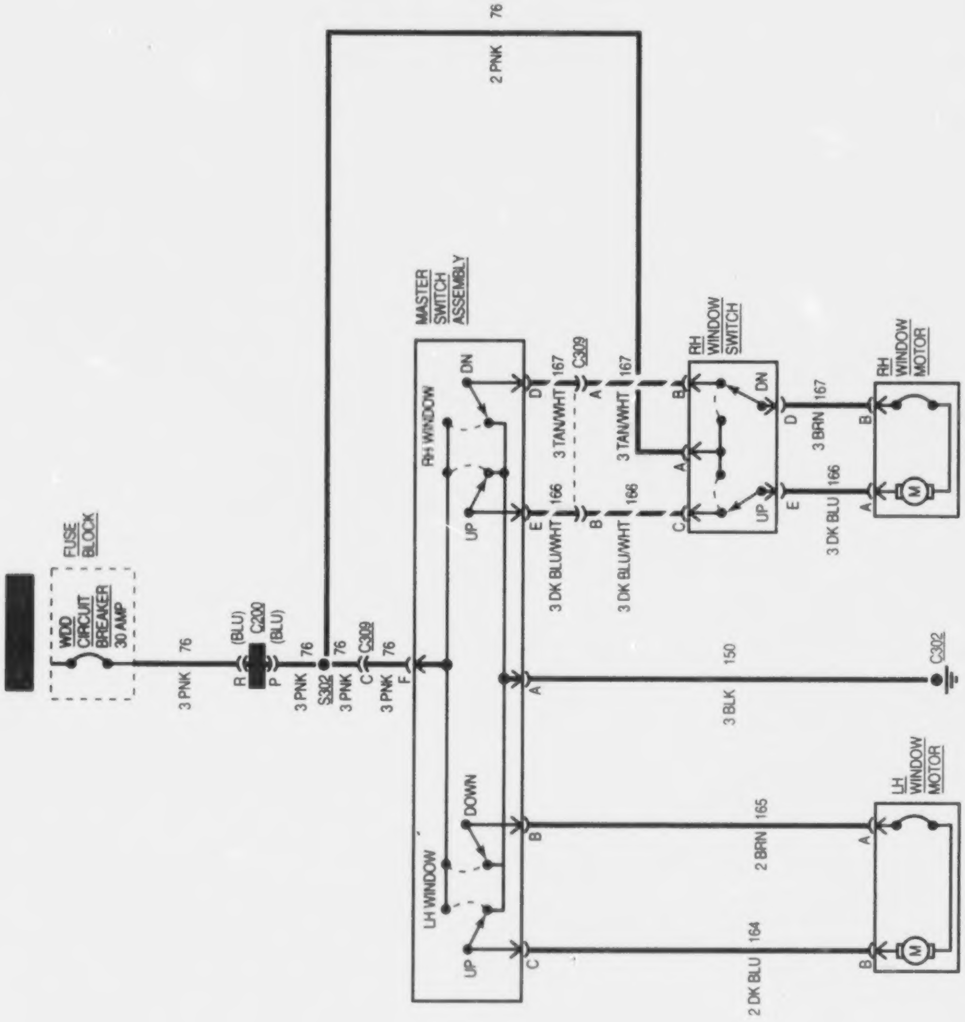
Simplified Windshield Wiper/Washer Circuit


FUSE BLOCK
WIPER FUSE
25 AMP
93
C234
1 WHT
B
WHT
93
WIPER/ WASHER SWITCH
WASHER SWITCH
ON
OFF
WIPER SWITCH
HI
LO
OFF
HI
LO
OFF
94
PNK
F
C234
1 PNK
94
92
PPL
E
1 PPL
92
95
DK GRN
D
1 DK GRN
95
91
GRY
C
1 GRY
91
C1
F
6
C2
A
5
B
4
1 YEL
196
C1
A
1
C
3
B
2
WIPER MOTOR
CIRCUIT BREAKER
CAPACITOR
CAPACITOR
MECHANICAL ARM
(ARM HOLDS CONTACT CLOSED UNTIL WIPERS PARK.)
PARK RELAY
WIPER MOTOR MODULE
C2
C
1 BLK
150
D
1 RED
228
D2
1 RED
228
1 LT BLU
227
D3
C100
C1
WASHER MOTOR
M
A
B
1 LT BLU
227
SEE GROUND DISTRIBUTION
G202
3 BLK
150
S203

725

Figure 3, Wiring Diagram C

Simplified Power Window Circuit


FUSE BLOCK
WDO CIRCUIT BREAKER 30 AMP
3 PNK 76
R (BLU) C200 (BLU) P
3 PNK 76
S302
3 PNK 76 C C309
3 PNK 76 F
2 PNK 76
MASTER SWITCH ASSEMBLY
RH WINDOW
DN
UP
D 3 TAN/WHT 167
C309
A 3 TAN/WHT 167
E 3 DK BLU/WHT 166
B 3 DK BLU/WHT 166
RH WINDOW SWITCH
B
A
C
DN
UP
D 3 BRN 167
E 3 DK BLU 166
RH WINDOW MOTOR
B
A
M
A 3 BLK 150
C302
LH WINDOW
DOWN
UP
B 2 BRN 165
C 2 DK BLU 164
LH WINDOW MOTOR
A
B
M

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Assignment Sheet 1

Directions

Use wiring diagrams A, B, and C to help you answer the following questions.

1. Which type of circuit is the simplified wiper/washer circuit?

   ____

2. On the headlight circuit (diagram A), list the devices that control the flow of electricity.

   ____

   ____

3. Which type of circuit is the simplified headlight circuit?

   ____

4. Name the load devices on the power window circuit (diagram B).

   ____

   ____

5. Which type of circuit is the simplified power window circuit?

   ____

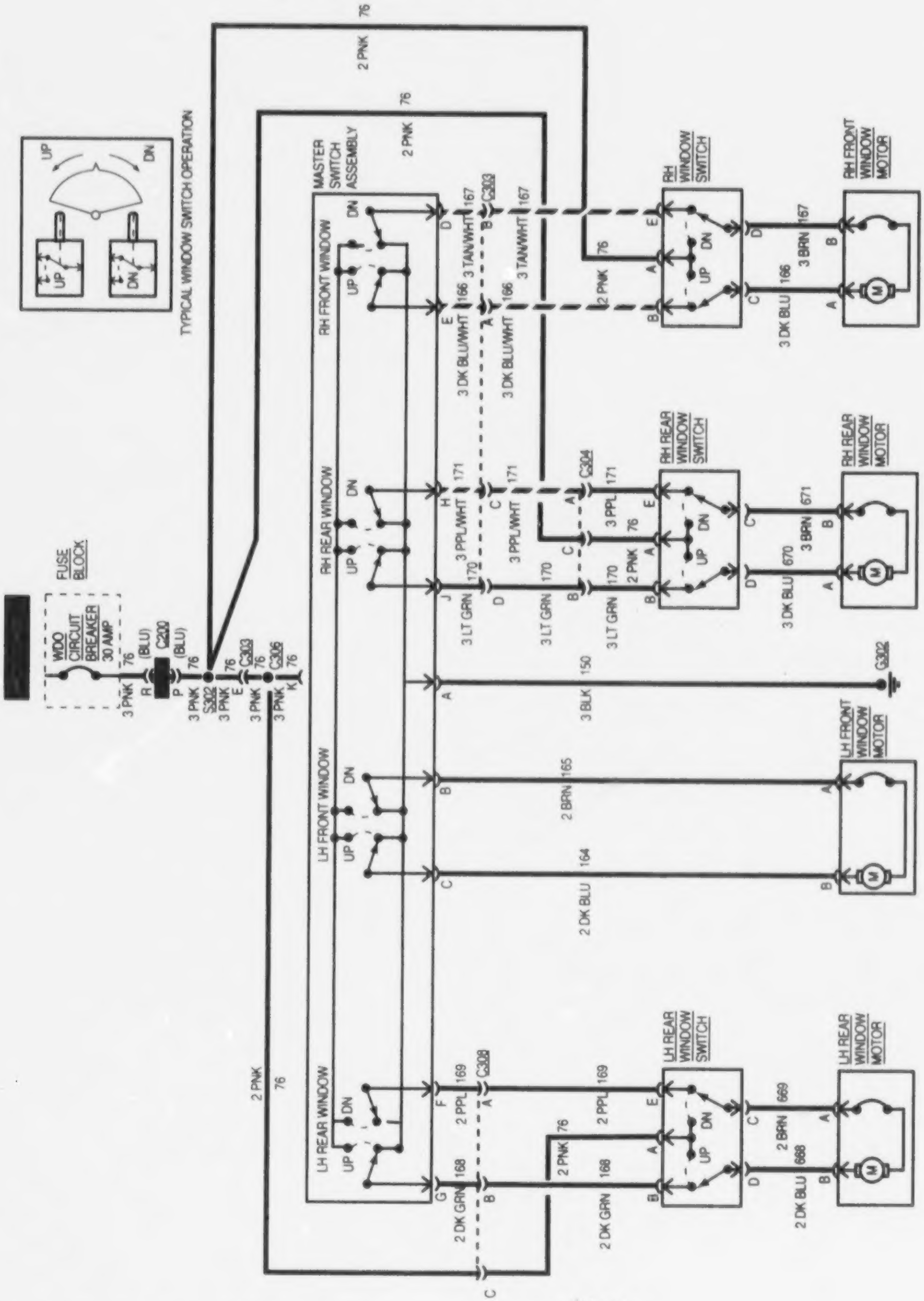
6. On diagram C, which device does the washer motor ground?

   ____

   ____

Figure 4, Wiring Diagram D

Power Window Circuit


TYPICAL WINDOW SWITCH OPERATION
UP
DN
FUSE BLOCK
WDO CIRCUIT BREAKER 30 AMP
3 PNK 76
C200 (BLU)
S302
C303
C306
MASTER SWITCH ASSEMBLY
RH FRONT WINDOW
RH REAR WINDOW
LH FRONT WINDOW
LH REAR WINDOW
2 PNK 76
3 TAN/WHT 167
3 DK BLU/WHT 166
3 PPL/WHT 171
3 LT GRN 170
3 BLK 150
2 BRN 165
2 DK BLU 164
2 PPL 169
2 DK GRN 168
C304
C308
G302
RH WINDOW SWITCH
RH FRONT WINDOW MOTOR
3 BRN 167
3 DK BLU 166
RH REAR WINDOW SWITCH
RH REAR WINDOW MOTOR
3 PPL 171
3 BRN 671
3 DK BLU 670
LH FRONT WINDOW MOTOR
LH REAR WINDOW SWITCH
LH REAR WINDOW MOTOR
2 BRN 669
2 DK BLU 668
M

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Assignment Sheet 1

You've been troubleshooting a problem having to do with a client's power windows. You've narrowed down the possible problems to either an intermittent short or an intermittent open in one of the circuits. Before you disassemble the doors and start testing, you need to know what type of circuit you're testing and what circuit devices are on the circuit. This is the only way you can know what and where to test.

Use wiring diagram D to help you answer the following questions.

7. Which type of circuit is Wiring Diagram D?

____

8. List all the devices on the left front power window circuit.

____

____

____

9. List all the devices on the left rear power window circuit.

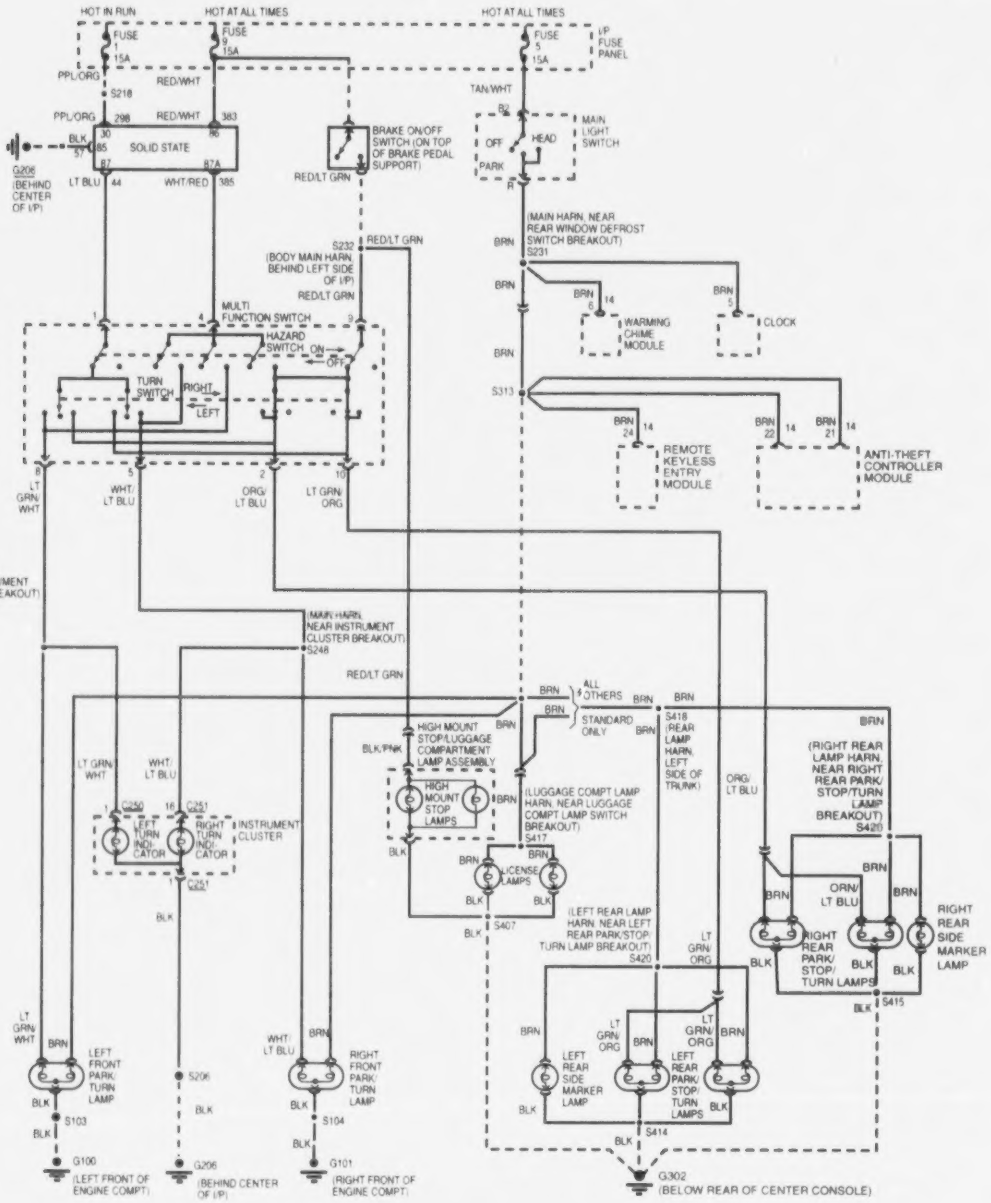
____

____

____

Figure 5, Wiring Diagram E

Parking/Stop/Turn Lamp System


HOT IN RUN
HOT AT ALL TIMES
HOT AT ALL TIMES
FUSE 1 15A
FUSE 9 15A
FUSE 5 15A
I/P FUSE PANEL
PPL/ORG
RED/WHT
S218
TAN/WHT
PPL/ORG 298
RED/WHT 383
BLK 57
30
86
85
SOLID STATE
87
87A
G206 (BEHIND CENTER OF I/P)
LT BLU 44
WHT/RED 385
BRAKE ON/OFF SWITCH (ON TOP OF BRAKE PEDAL SUPPORT)
RED/LT GRN
B2
MAIN LIGHT SWITCH
OFF
HEAD
PARK
R
(MAIN HARN, NEAR REAR WINDOW DEFROST SWITCH BREAKOUT) S231
BRN
S232
RED/LT GRN
(BODY MAIN HARN, BEHIND LEFT SIDE OF I/P)
RED/LT GRN
BRN 6 14
WARNING CHIME MODULE
BRN 5
CLOCK
MULTI FUNCTION SWITCH
1
4
9
HAZARD SWITCH
ON
OFF
TURN SWITCH
RIGHT
LEFT
S313
BRN 24 14
REMOTE KEYLESS ENTRY MODULE
BRN 22 14
BRN 21 14
ANTI-THEFT CONTROLLER MODULE
8
5
2
10
LT GRN/WHT
WHT/LT BLU
ORG/LT BLU
LT GRN/ORG
(MAIN HARN, NEAR INSTRUMENT CLUSTER BREAKOUT) S247
(MAIN HARN, NEAR INSTRUMENT CLUSTER BREAKOUT) S248
RED/LT GRN
BRN
ALL OTHERS
STANDARD ONLY
S418 (REAR LAMP HARN, LEFT SIDE OF TRUNK)
HIGH MOUNT STOP/LUGGAGE COMPARTMENT LAMP ASSEMBLY
BLK/PNK
HIGH MOUNT STOP LAMPS
(LUGGAGE COMPT LAMP HARN, NEAR LUGGAGE COMPT LAMP SWITCH BREAKOUT) S417
LT GRN/WHT
WHT/LT BLU
1 C250
16 C251
LEFT TURN INDICATOR
RIGHT TURN INDICATOR
INSTRUMENT CLUSTER
1 C251
BLK
LICENSE LAMPS
S407
ORG/LT BLU
(RIGHT REAR LAMP HARN, NEAR RIGHT REAR PARK/STOP/TURN LAMP BREAKOUT) S420
ORN/LT BLU
RIGHT REAR PARK/STOP/TURN LAMPS
RIGHT REAR SIDE MARKER LAMP
S415
(LEFT REAR LAMP HARN, NEAR LEFT REAR PARK/STOP/TURN LAMP BREAKOUT) S420
LT GRN/ORG
LEFT FRONT PARK/TURN LAMP
S103
S206
RIGHT FRONT PARK/TURN LAMP
S104
LEFT REAR SIDE MARKER LAMP
LEFT REAR PARK/STOP/TURN LAMPS
S414
G100 (LEFT FRONT OF ENGINE COMPT)
G206 (BEHIND CENTER OF I/P)
G101 (RIGHT FRONT OF ENGINE COMPT)
G302 (BELOW REAR OF CENTER CONSOLE)

You will now investigate a wiring diagram for a Ford Motor Company vehicle. On this diagram you will need to able to trace the power flow through the circuit and all its devices. Being able to do this will greatly enhance your diagnostic ability. It will help you better understand how electricity flows through a circuit.

Use wiring diagram E to help you answer the following questions.

10. On Wiring Diagram E, if the main light switch is turned to the "Park" position, list all lamps that will light.

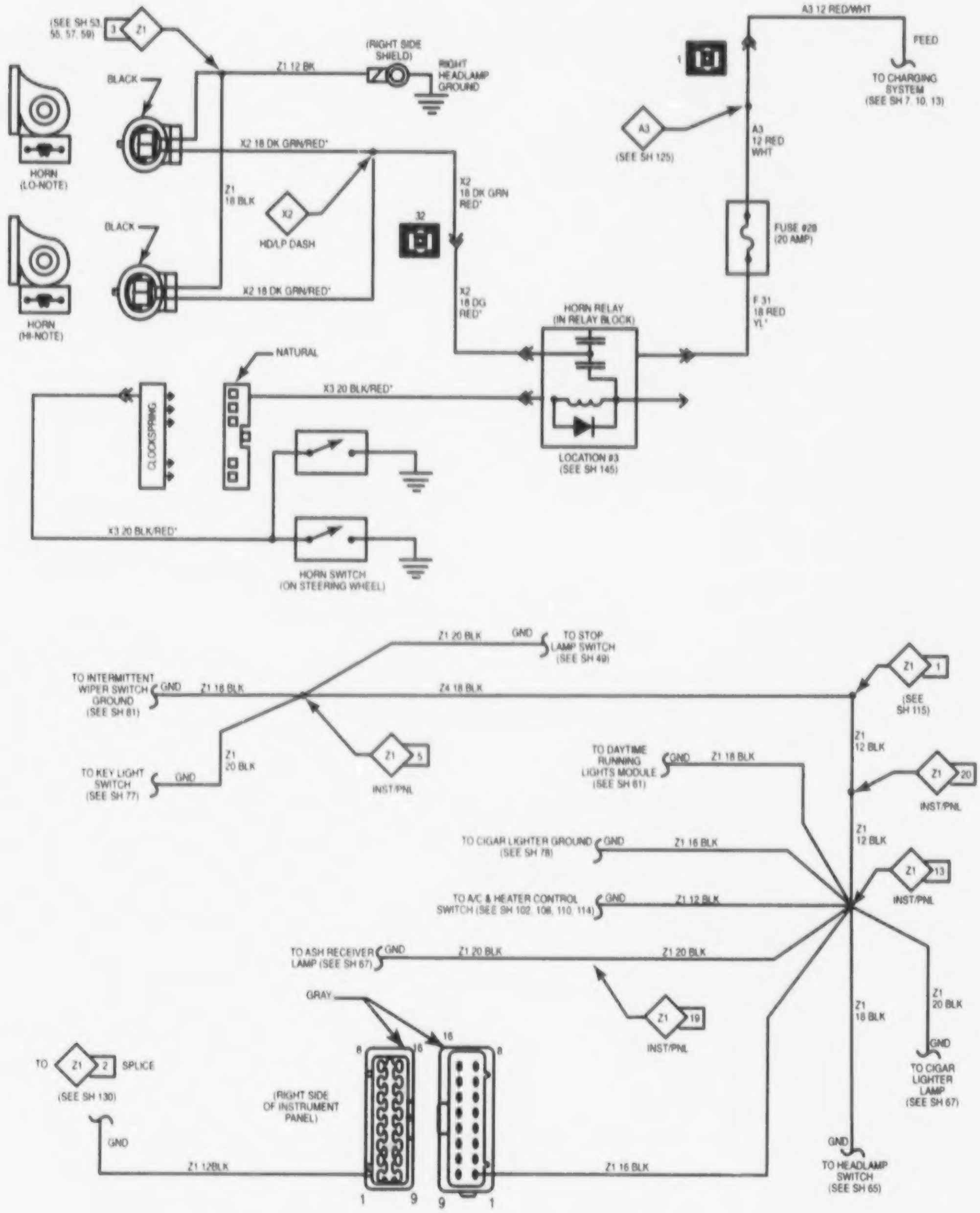
11. If the brake on/off switch is closed, and neither the hazard light or the turn signals are activated, list all brake lamps that would be lit up.

12. In what ignition switch position(s) will the brake light circuit operate?

13. In what ignition switch position(s) will the turn signal circuit operate?

Figure 6, Wiring Diagram F

Horn System Circuit


(SEE SH 53, 55, 57, 59)
3
Z1
(RIGHT SIDE SHIELD)
Z1 12 BK
RIGHT HEADLAMP GROUND
BLACK
HORN (LO-NOTE)
X2 18 DK GRN/RED*
Z1 18 BLK
X2
HD/LP DASH
BLACK
HORN (HI-NOTE)
X2 18 DK GRN/RED*
32
X2 18 DK GRN RED*
X2 18 DG RED*
A3 12 RED/WHT
FEED
TO CHARGING SYSTEM (SEE SH 7, 10, 13)
1
A3
(SEE SH 125)
A3 12 RED WHT
FUSE #29 (20 AMP)
F 31 18 RED YL*
HORN RELAY (IN RELAY BLOCK)
LOCATION #3 (SEE SH 145)
NATURAL
X3 20 BLK/RED*
CLOCKSPRING
X3 20 BLK/RED*
HORN SWITCH (ON STEERING WHEEL)
Z1 20 BLK
GND
TO STOP LAMP SWITCH (SEE SH 49)
TO INTERMITTENT WIPER SWITCH GROUND (SEE SH 81)
GND
Z1 18 BLK
Z4 18 BLK
Z1
1
(SEE SH 115)
Z1 20 BLK
TO KEY LIGHT SWITCH (SEE SH 77)
GND
Z1
5
INST/PNL
Z1 12 BLK
Z1
20
INST/PNL
TO DAYTIME RUNNING LIGHTS MODULE (SEE SH 81)
GND
Z1 18 BLK
Z1 12 BLK
TO CIGAR LIGHTER GROUND (SEE SH 78)
GND
Z1 16 BLK
Z1
13
INST/PNL
TO A/C & HEATER CONTROL SWITCH (SEE SH 102, 108, 110, 114)
GND
Z1 12 BLK
TO ASH RECEIVER LAMP (SEE SH 67)
GND
Z1 20 BLK
Z1 20 BLK
Z1
19
INST/PNL
Z1 20 BLK
Z1 18 BLK
GND
TO CIGAR LIGHTER LAMP (SEE SH 67)
GRAY
8
16
16
8
1
9
9
1
(RIGHT SIDE OF INSTRUMENT PANEL)
TO
Z1
2
SPLICE
(SEE SH 130)
GND
Z1 12BLK
Z1 16 BLK
GND
TO HEADLAMP SWITCH (SEE SH 65)

Assignment Sheet 1

In the previous exercises you have looked at General Motors and Ford wiring diagrams. You will now look at a DaimlerChrysler Corporation wiring diagram. As you study the diagram, you will see that, although each company's wiring diagrams look different, you can still find all the components of a circuit.

Use wiring diagram F to help you answer the following questions.

14. Which type of circuit is Wiring Diagram F? ____________________

15. List all the devices on the horn system circuit.

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Objective 9

Assignment Sheet 2—Perform Calculations Using Units of Electrical Measurement

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Directions were followed	______
• Answered a minimum of 26 of the 30 questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading Writing Mathematics

Introduction

Many electrical repairs will involve using testing equipment that will measure volts, amperes, and ohms in numerical values—some extremely small and some extremely large. Testing equipment has meters that read very large numbers and very small numbers by shifting the decimal point and using a prefix scale. Refer to Supplement 1 for information on the system of prefixes, values, and symbols to better understand how the metric system and a group of prefixes can change the size of the unit. Adding, subtracting, multiplying, and dividing these numbers can also require the technician to convert values into designated electrical units. Becoming familiar with the metric system will make it easier for the Electrical Systems Technician to work with very large or very small numbers.

Directions

Instructions for current

Convert the values to electrical units using Supplement 1. Write your answers on the blank lines provided.

1. 0.000788 A equal how many milliamperes? ______________________
2. 0.000788 A equal how many µA? ______________________
3. 50 µA equal how many amperes? ______________________
4. 11 mA equal how many amperes? ______________________
5. 750 µA equal how many mA? ______________________
6. 30 mA plus 25 microamperes equal how many amperes? ______________

Assignment Sheet 2

7. 55 mA plus 11 A equal how many amperes? ______________________

8. 15 A minus 10 mA equal how many amperes? ______________________

9. 16 A equal how many microamperes? ______________________

10. 235,000,000 amperes equal many MA? ______________________

Instructions for voltage

Convert the values to electrical units using Supplement 1. Write your answers on the blank lines provided.

11. 500 kV equal how many MV? ______________________

12. 243 mV equal how many volts? ______________________

13. 10 V equal how many millivolts? ______________________

14. 3 MV equal how many kV? ______________________

15. 3MV equal how many volts? ______________________

16. 300 millivolts equal how many kilovolts? ______________________

17. 500 kV plus 243 mV equal how many volts? ______________________

18. 45 volts minus 243 mV equal how many volts? ______________________

19. 1 kV equals how many volts? ______________________

20. 1000 volts equal how many kilovolts? ______________________

Instructions for resistance

Convert the values to electrical units using Supplement 1. Write your answers on the blank lines provided.

21. 32 k Ω equal how many Ω? ______________________

22. 32M Ω equal how many ohms? ______________________

23. 3500 ohms equal how many kΩ? ______________________

24. 3.5 k Ω equal how many Ω? ______________________

25. 2200 Ω equal how many kΩ? ______________________

26. 1,000 Ω plus 10 kilohms equal how many Ω? ______________________

27. 2,000 Ω minus 100 miliohms equal how many Ω? ______________________

28. 120 kΩ equal how many ohms? ____________________

29. 6.3 MΩ equal how many kilohms? ____________________

30. 11 mΩ equal how many ohms? ____________________

Objective 10

Assignment Sheet 3—Prepare to Measure Current, Voltage, Resistance, and Frequency With a Multimeter

Name ________________________ Overall Rating __________

Date ________________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 13 of the 17 questions correctly per Answers to Assignment Sheet 3	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking

Introduction

After you've identified types of circuits and circuit devices, but before you actually test the devices, you need to perform one additional step—prepare to measure current with a multimeter (DVOM). Think of it this way. When it's time to get out of bed and go to school, you don't just get up and go—you've got to get ready. Even though you know which school to go to and which class to go to (you may even know the teacher's name), there are still a few "preparation" activities—get dressed, brush your teeth, fix your hair, etc. After all these things are done, then you can go to school. That's how it is with measuring current—you know which circuit to test, what type of circuit it is, which device to test, and even Ohm's law. Now you will do the final step and prepare to measure current.

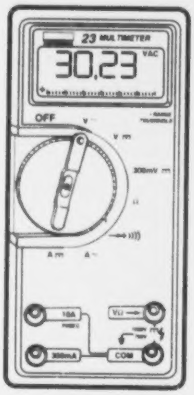
This Assignment Sheet provides some exercises that will teach you the steps to follow in preparing to measure current. Those steps are: **Select**, **Calibrate**, **Open**, and **Connect**.

Assignment Sheet 3

To prepare to measure current, follow the steps below.

Figure 1

DVOM



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1—Select

Most DVOM's have several test lead plug-ins, or jacks, and selector knob positions. (Figure 1) You must select the proper jacks and the correct selector knob position according to the amount of current in the circuit you're testing. One of the jacks used for measuring amps is for large or unknown amounts of current. The other jacks are for smaller amounts of current. The jack and knob positions for larger or unknown amps are labeled with a number followed by an "A" (10A or 15A, for example). Selections for smaller amps will be labeled with a number followed by an "mA" (300 mA, for example). The numbers indicate the maximum amount of current that may be measured without damaging the multimeter or blowing its fuse. If you don't know the amperage of the circuit you're testing, choose the largest rating. If the DVOM measures both AC and DC, insure that the switches or knobs are set to the proper AC/DC setting. Most of the time you'll be testing DC circuits. Most handheld DVOMs have a maximum amperage rating of between 10 and 15 amps. Use common sense. If the fuse rating for the circuit is 30 amps, and the circuit is continually blowing fuses, then do NOT attempt to measure amperage, because common sense tells you that the circuit is using in excess of 30 amps. Some multimeter manufacturers produce a shunt, sometimes called a current clamp, that can be wired in series with the positive lead, to allow the meter to measure amperage up to 150 amps.

The positive (red) lead connects to the appropriate amp jack, while the negative (black) lead always connects to the common (comm) jack.

Refer to the DVOM manufacturer's manual for explicit instructions on which selections you should make.

Note: You may have to perform some calculations in order to determine which jack to use and where to set the knob. Refer to Supplement 1, "Values, Prefixes, and Symbols" for an explanation of units of measure.

2—Calibrate

After you connect the leads to the DVOM, and you have turned the selector knob to the proper selection, touch the leads together. The display should read zeros. If it doesn't, keep the leads connected until the meter reads zero. Usually this should take no more than 5 seconds

If the display fails to read zeros, then the leads are faulty or the meter is out of calibration and should not be considered accurate.

Figure 2

Sample Circuit with Fuse Removed

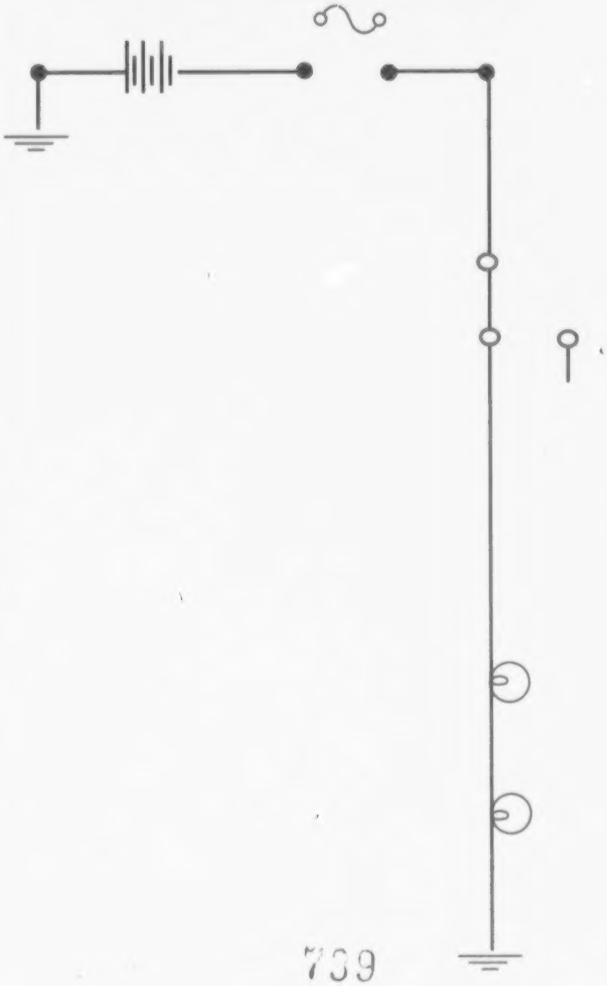
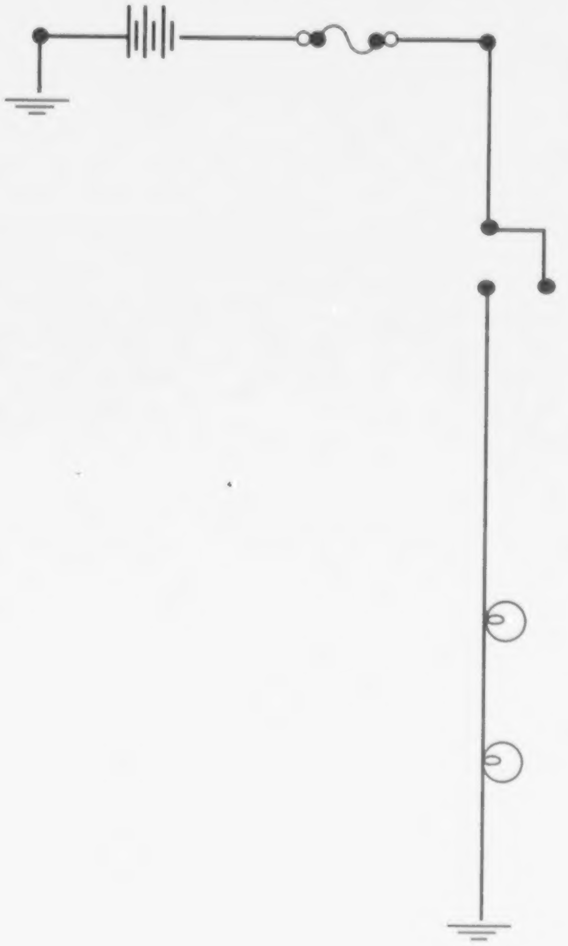


Figure 3

Sample Circuit with Switch Open



3—Open

An open refers to opening the circuit so that current will not flow while you are connecting the DVOM to the circuit. Many times this first open (the one that prevents spiking) already exists. For example, the horn, the brake light, the headlights, and the power window motor switches are all normally open. In those cases where the switch is already open, you don't need to create this open. You should, however, ensure that the switch that you're assuming is open is actually open. If you can't locate an easily accessible switch on the circuit you are testing, turn the ignition switch off, then verify that the circuit is unpowered.

740

When a technician is measuring current, an open also refers to the procedure of opening the circuit to place the DVOM in series in the circuit. In Step 4 you'll connect to each side of the second above mentioned open. The first above mentioned opening will remain open during the entire time you're connecting the DVOM to the circuit. By opening an additional switch, you prevent damage to the DVOM caused by spiking when you connect the test leads. The first open in the circuit will be closed after the connections are made in Step 4. Common ways to open the circuit to connect the DVOM to the circuit are removing a fuse, opening a connection, or removing a small section of wire in the circuit (Figures 2 and 3). Do not cut a section of wire unless it's absolutely necessary. If you can't locate a section of wire between two connectors to remove, then remove an appropriate fuse or open a connection. Realize that when you measure current, you have to physically open that circuit and place the DVOM in the open you have created so that current can flow through the meter and the circuit.

4—Connect

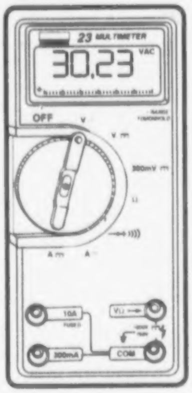
In order to measure current, it must flow through the instrument; therefore, the DVOM must be connected in series with a current path. The meter's probes must be placed in the circuit being tested in a place in the circuit so that all the current going through the circuit goes through the meter also. Place the probes on each side of the opening in the circuit (Figures 2 and 3). First connect the positive (+) lead to a point on the circuit on the positive side of the opening, then place the negative (-) lead to the negative side of the opening. After the connections have been made, close the first open that you created in Step 3.

Note: If you resorted to opening the ignition switch as your first open, don't close the circuit by turning the key all the way to Start, just turn it to On.

To prepare to measure voltage, follow the following steps below.

Figure 4

DVOM



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Assignment Sheet 3

1—Select

When you prepared to measure current you had to select the appropriate jacks and turn the selector knob to the correct position. Preparing to measure voltage has similar requirements. One of the jacks that you use for measuring volts is for large or unknown amperage, the other jacks are for smaller amounts. The knob position for larger or unknown volts is often labeled with a number followed by a "V" (12 V or 120 V, for example). Selections for smaller voltages will often be labeled with a number followed by an "mV" (300 mV, for example) (Figure 4). The numbers indicate the maximum voltage and amperage that may be measured without damaging the multimeter. If you don't know the volts or amps of the circuit you're testing, choose the largest rating. If the DVOM measures both AC and DC, insure that the switches or knobs are set to the proper AC/DC setting. Most of the tests for voltage on automotive electrical circuits will be on DC circuits.

Refer to the DVOM manufacturer's manual for detailed instructions on which selections you should make.

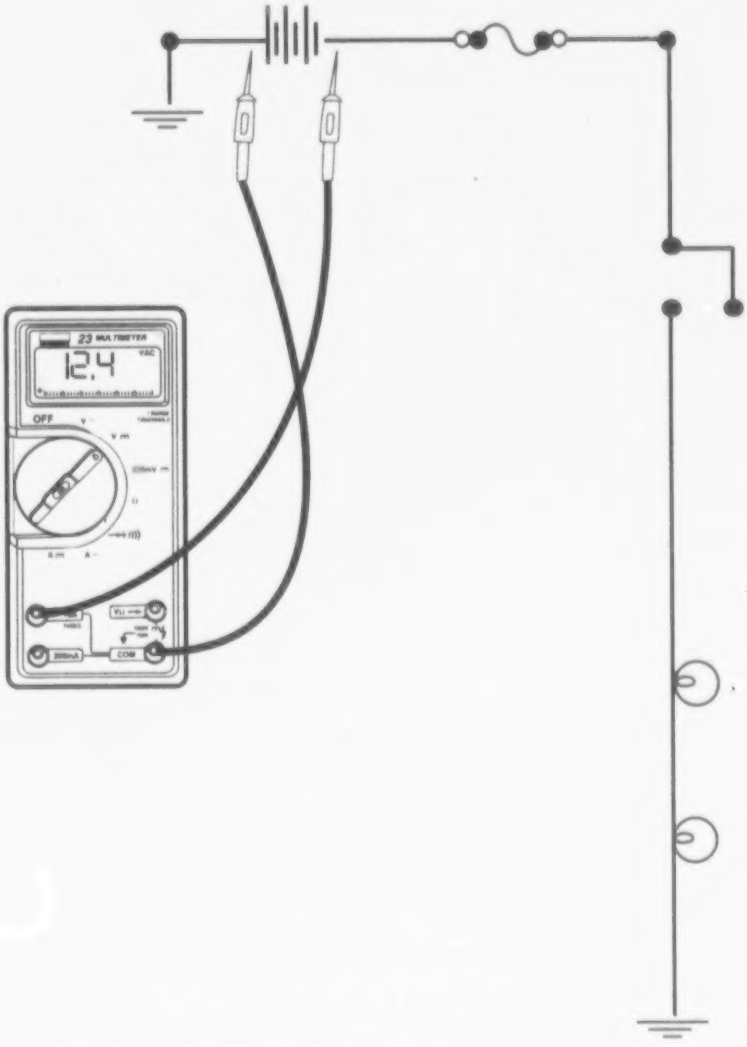
Note: You may have to perform some calculations in order to determine which jack to use and where to set the knob. Refer to Supplement 1, "Values, Prefixes, and Symbols" for an explanation of units of measure.

2—Calibrate

Refer to the calibration steps for measuring current. You calibrate the same for voltage as you do for amperage.

Figure 5

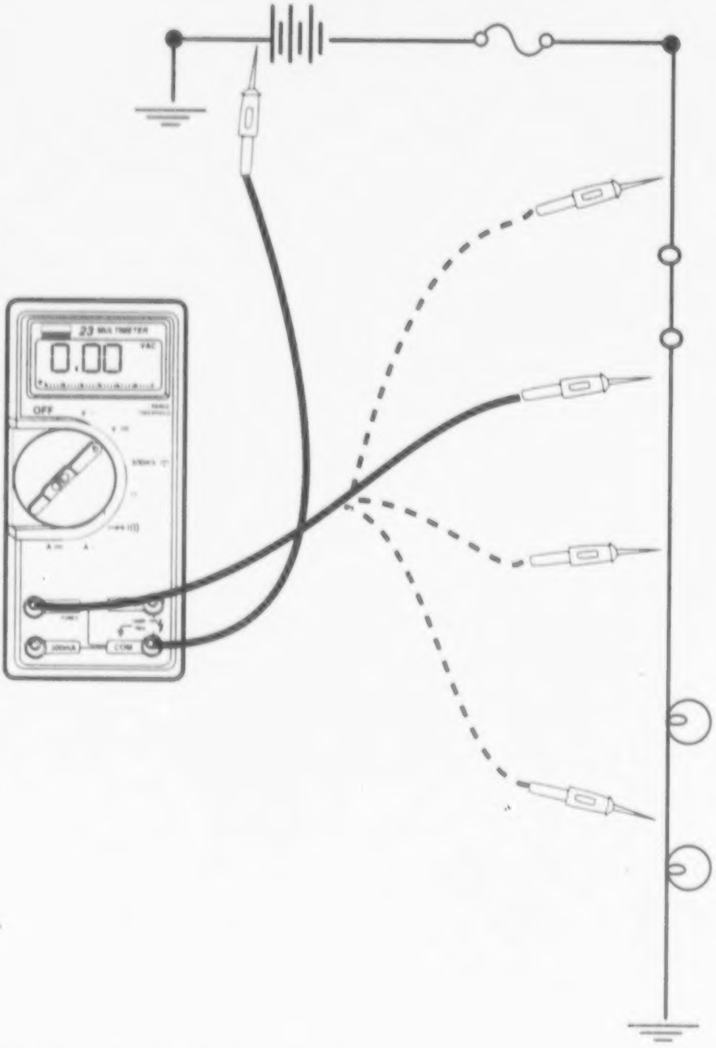
Sample Circuits with DVOM Connected


23 MULTIMETER
12.4
VAC
OFF
COM
200mA

Used with permission of DaimlerChrysler Corp.

Figure 6

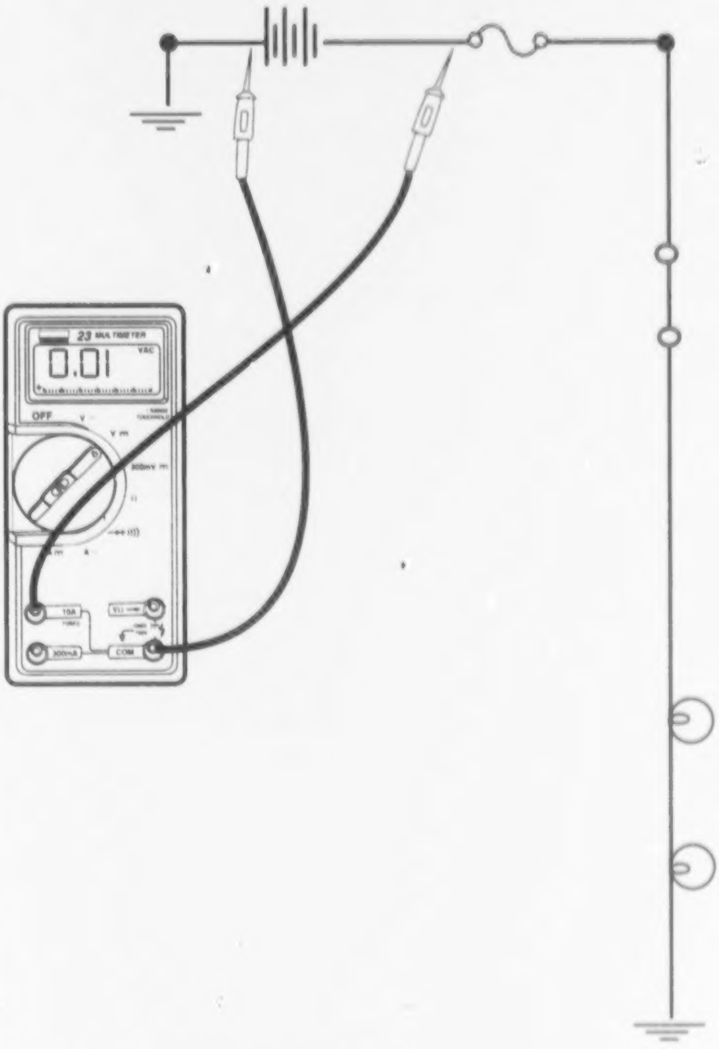
Sample Circuits with DVOM Connected


23 MULTIMETER
0.00
VAC
OFF
300mA
COM

Used with permission of DaimlerChrysler Corp.

Figure 7

Sample Circuits with DVOM Connected



Used with permission of DaimlerChrysler Corp.

3—Open

You can measure voltage at any time because the circuit does not have to be open to test for electrical pressure. It will not damage the meter while it is in the voltage position. At times it can be helpful to open the circuit **before** connecting to it so you can see how voltage reacts when it is applied to a circuit. The best way to open the circuit is to open a switch. After you've connected to the circuit you'll close the switch to allow the current to flow through the circuit and the DVOM.

Note: Many times the open already exists. For example, the horn, the brake light, the headlights, and the power window motor switches are all normally open. You should ensure that the switch that you're assuming is open is actually open.

4—Connect

In order to measure voltage, current must flow through the DVOM as well as the circuit; therefore the DVOM must be connected in **parallel** in the circuit. There are three main voltage tests used to diagnose an electrical malfunction. The first test is **Source Voltage**. This tests the amount of electrical pressure that is available for the circuit (how much voltage is in the battery). The proper connection for measuring source voltage is the positive (red) lead to the positive side of the battery and the negative (black) lead to the negative side of the battery (see Figure 5).

The second test is **Applied Voltage**. This tests the amount of electrical pressure that is at any point in the circuit. The negative (black) lead always connects to the negative battery post or to a good chassis ground. The negative lead can be used to test for voltage at various points in the electrical circuit. For example, you can test for voltage at the positive side of the fuse and the negative side of the fuse to see if the fuse is good (voltage on both sides of the fuse) or open (voltage on the positive side of the fuse only). See Figure 6 for common hookups to measure applied voltage.

The third test is **Voltage Drop**. This tests the amount of electrical pressure that is being used to push current through a device in the circuit. You must realize that the sum of all the voltage drops in the circuit should equal source voltage. The proper lead connections for voltage drop are the negative lead to the negative side of the component being tested and the positive lead to the most positive side of the circuit. Look at Figure 7 to see how to test the voltage drop of a fuse in a circuit. You must realize that if voltage drop of the fuse is equal to source voltage, then the fuse would be open.

Note: If the circuit is live only when the engine is running or the ignition is turned on, you must start the engine or turn the ignition on in order for current to flow through the circuit and DVOM.

To prepare to measure resistance, follow the steps below.

Note: To prevent damage, never connect the multimeter in the ohmmeter function to a voltage source. Disconnect the part of wire or component to be tested from the circuit.

Most modern ohmmeters are what as known as "autoranging" or automatic range selection. The ohmmeter will adjust itself to the proper range level. You can tell the difference by how many resistance selections are on the meter. In Figure 1 there is only one resistance position on the control knob, Ω, so it is an autoranging ohm meter. If a meter has several positions such as 200Ω, 2KΩ, 20KΩ, 200KΩ, 2MΩ and 20MΩ, then you can be relatively certain that the meter is not autoranging. If you are using one of these old meters, always start at the highest resistance range 20MΩ and work to the smallest resistance range 200Ω. If you start on the 200Ω range and the resistance of the component being tested is 2000Ω, the meter would show that the component being tested is faulty (open) when it was actually not properly prepared to measure.

The resistance of certain electrical system parts is specified in service manuals, and the ohmmeter function of the meter often provides the only means to determine if those parts are serviceable.

When the test leads are held apart, no current can flow in the ohmmeter circuit. This represents an extremely large or infinite resistance between the test leads. When the test leads are touched together, the ohmmeter circuit is completed and current can flow.

To "zero out" the ohmmeter, touch the leads to the terminals of the circuit to be tested. It is not necessary to observe test lead polarity if the circuit is open except when testing a circuit that contains a diode. Refer to the usage instructions included with the test equipment for additional information.

1—Select

To properly select the proper knob setting on the multimeter in Figure 1 place the knob to the "Ω" position. The negative lead is hooked to the comm jack at the bottom of the meter and the positive lead connects to the "V/Ω" jack at the bottom of the meter.

2—Calibrate

As before in current and voltage measurement you should hook the leads together and the meter display should show 0.00Ω of resistance. **You need to realize on an autoranging meter that the only way to know what range you are in is to look at the display on the meter. It will show Ω for ohms of resistance, KΩ for thousands of ohms of resistance, and MΩ for millions of ohms of resistance. Be sure to read the meter carefully.**

3—Open

Always remove the component being tested from the circuit before connecting the meter to the component. If you are measuring the entire circuit resistance, make sure the circuit is not connected to a power source. If it is, it could damage the meter.

4—Connect

To connect the meter to the component or circuit, simply place one lead at one end of the electrical pathway and the other lead to the other end of the electrical pathway.

Note: Multimeters vary from manufacturer to manufacturer. Do not try to use a multimeter without reading and understanding the operator's manual.

Assignment Sheet 3

To prepare to measure frequency, follow the steps below.

Note: Some DVOM's limit the range of the frequency that can be measured. When purchasing a multimeter, make sure the range of the frequency meter is adequate to accomplish the work you're intending to do.

The frequency of certain electrical system components is specified in service manuals. Without a way to test frequency, the ohmmeter function of the meter often provides the only means to determine if those parts are serviceable.

1—Select

To properly select frequency on a multimeter, the knob can be placed to the "frequency" position or the meter will have a separate button designated for frequency. The negative lead will plug into the comm jack at the bottom of the meter, and the positive lead will be plugged into the "Freq" jack at the bottom of the meter.

2—Calibrate

As before in the current, voltage and resistance measurement, you should touch the two leads together and the meter display should show 0.00 Hz.

3—Open

Always remove the component being tested from the circuit before connecting the meter to the component. Stray voltage from the circuit could give you a false reading.

4—Connect

To connect the meter to the component or circuit, simply place one lead at one end of the electrical pathway and the other lead to the other end of the electrical pathway.

Notice: Multimeters vary from manufacturer to manufacturer. Do not try to use a multimeter without reading and understanding the operator's manual.

Now that we have covered the procedures of how to prepare to measure with a multimeter, let's answer some questions and see if your understanding is correct.

Materials list

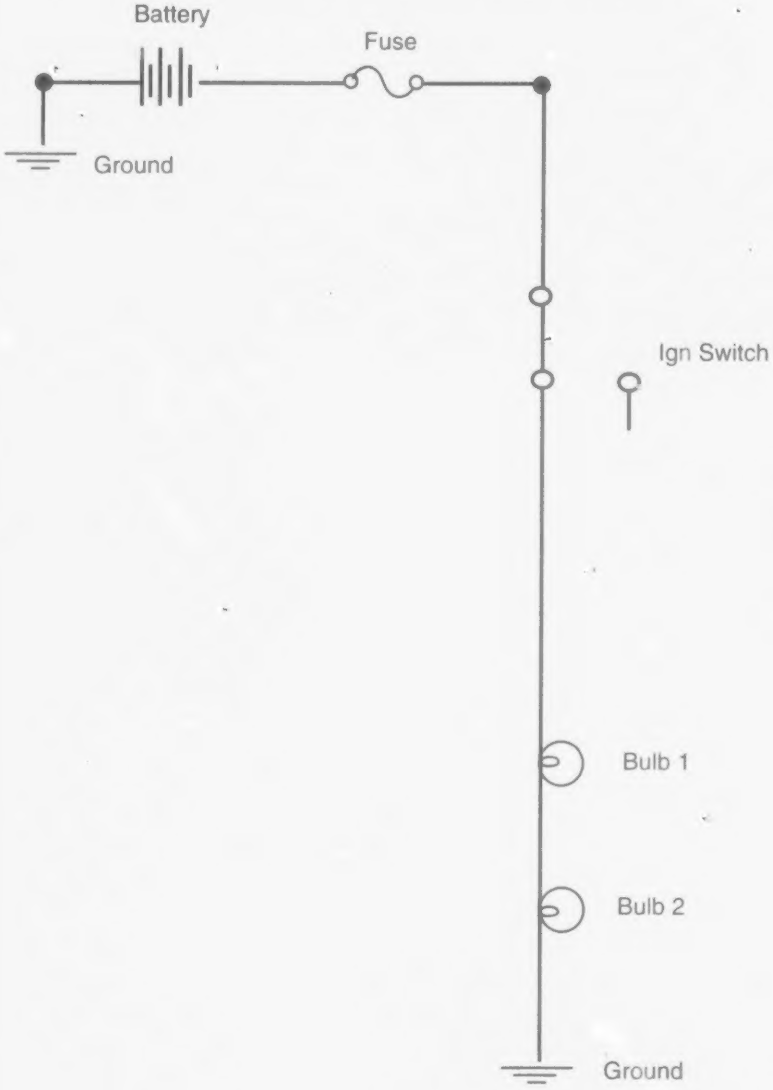
- Supplement 1, Values, Prefixes, and Symbols
- Supplement 2, Multimeters
- You may also want to refer to handouts or other information on current, voltage, resistance, and Ohm's Law.
- Examples of multimeters
- Multimeter manufacturer's instruction manual

Directions

Refer to any of the materials listed above to answer the questions that follow the diagrams.

Figure 8

Sample Circuits with DVOM Connected


Battery
Fuse
Ground
Ign Switch
Bulb 1
Bulb 2
Ground

749

Figure 9

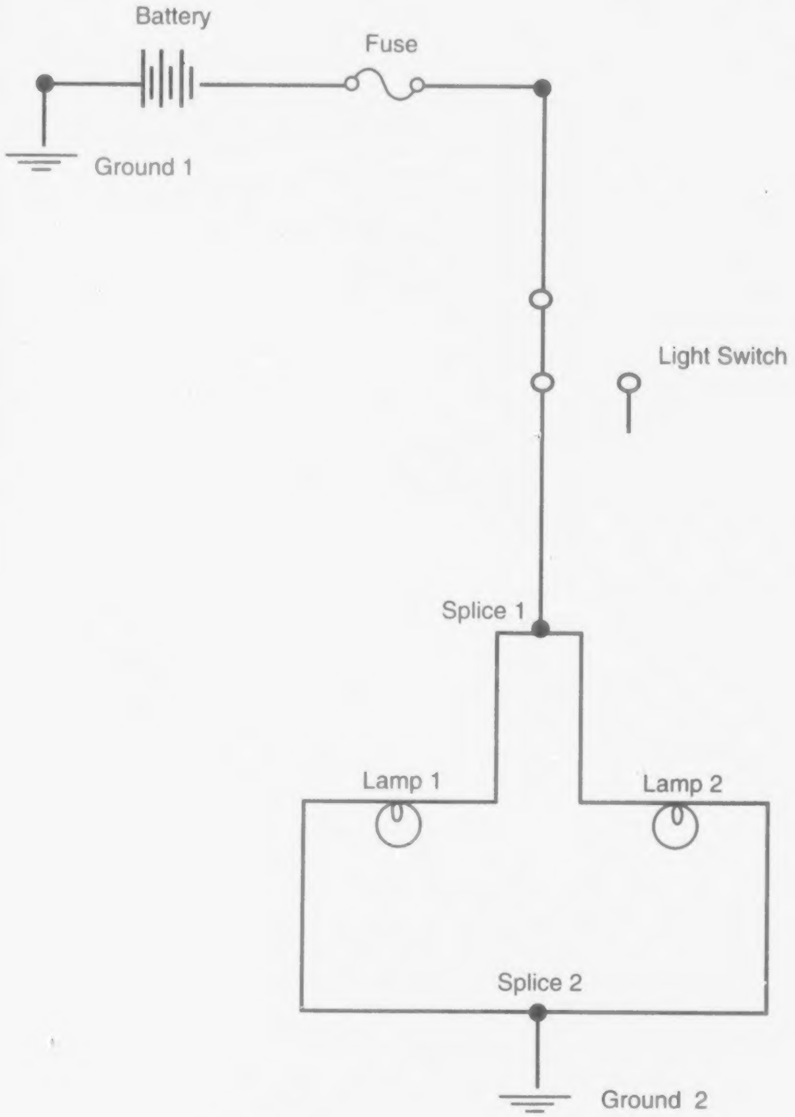

Battery
Fuse
Ground 1
Light Switch
Splice 1
Lamp 1
Lamp 2
Splice 2
Ground 2

Figure 10

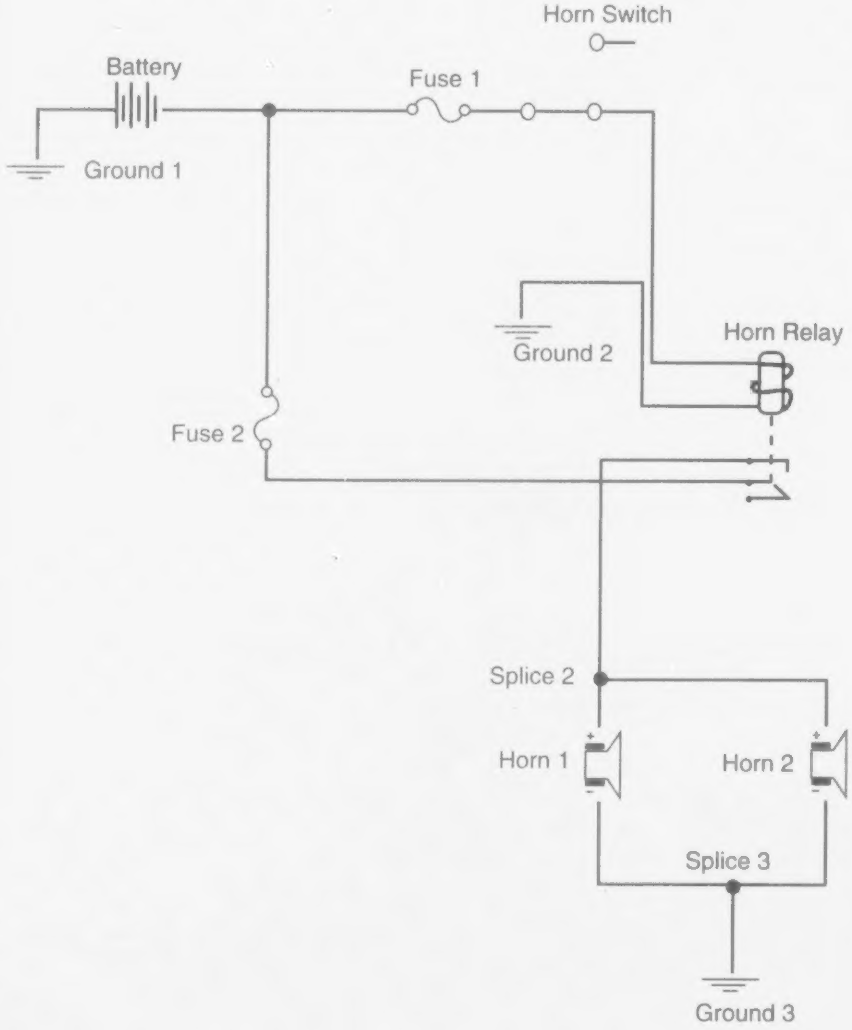
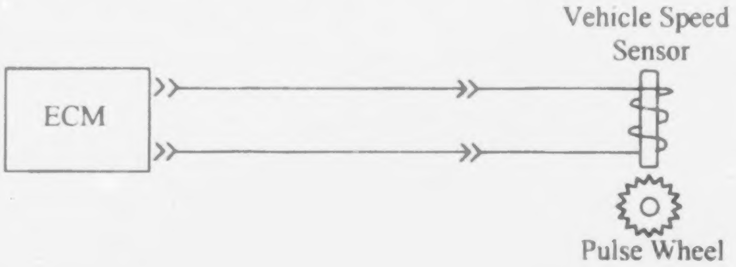
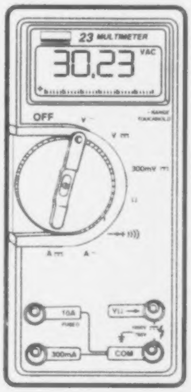

Horn Switch
Battery
Fuse 1
Ground 1
Ground 2
Horn Relay
Fuse 2
Splice 2
Horn 1
Horn 2
Splice 3
Ground 3

Figure 11


Vehicle Speed Sensor
ECM
Pulse Wheel

Assignment Sheet 3

Figure 12



1. List where to correctly connect the leads to the multimeter to measure voltage.

____

2. Using Figure 8 of a basic sample circuit, where would you connect the multimeter leads to measure source voltage?

____

3. Using Figure 8, what component should be removed to measure current and explain the process to correctly hook up the ammeter?

____

4. On Figure 8, where would you hook the voltmeter leads to measure the voltage drop of bulb 1?

____

5. Using Figure 8, where would you connect the voltmeter leads to measure applied voltage to bulb 1?

____

6. When setting up the multimeter to measure amperage, where would you connect the leads to the multimeter in Figure 12?

____

7. Using Figure 9, explain how to measure resistance of lamp 1.

____

8. Using Figure 9, explain where to place the leads of the voltmeter if you wanted to measure the voltage drop of the wire between splice 1 and lamp 2.

9. To measure amperage of the circuit in Figure 9, what component should be removed to connect the ammeter?

10. You are measuring the voltage drop between splice 2 and the negative side of the battery on Figure 9. The voltmeter reading indicates 11.8 volts. What does this indicate?

11. How could you verify the problem in question 10?

12. Using Figure 10, what component would you remove to measure the amperage the horns would be using?

13. Using the multimeter in Figure 12, what knob position would you place the meter in to measure resistance?

14. On Figure 10, where would you connect the voltmeter to measure voltage drop of the horn switch?

15. On Figure 10, where would you connect the voltmeter to measure applied voltage to horn 1?

16. On Figure 11, how would you **Select** the meter to test the Vehicle Speed Sensor?

17. On Figure 11, what would you "**Open**" to test this circuit? The ECM or VSS?

Objective 11

Assignment Sheet 4—Calculate Resistance In Sample Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 4	______

Basic Skills

Reading Mathematics

Introduction

Knowing how much resistance should be in a circuit is extremely helpful when diagnosing an electrical problem. Calculating resistance is simple if you have Ohm's law for the calculations. Ohm's law states that "resistance is equal to voltage divided by amperage." If you know the voltage being applied to the circuit and the amperage flowing through the circuit, you can use the Ohm's Law formula to calculate resistance.

Resistance=voltage/amperage

In simple, or one-load circuits, finding resistance is easy.

Example

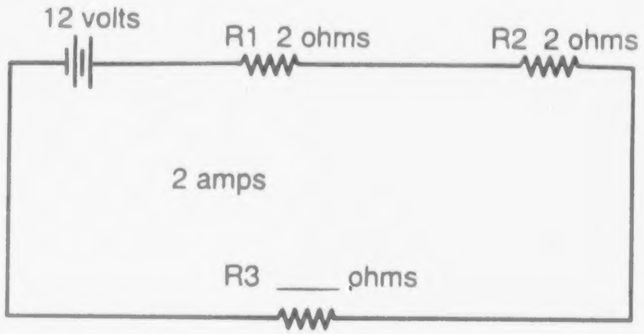
A circuit has 12 volts and 3 amps of current flow through the circuit. How much resistance is in the circuit?

Resistance=12 volts divided by 3 amps
Resistance=12/3
Resistance=4 ohms

Assignment Sheet 4

Figure 1

In series circuits


12 volts
R1 2 ohms
R2 2 ohms
2 amps
R3 ____ ohms

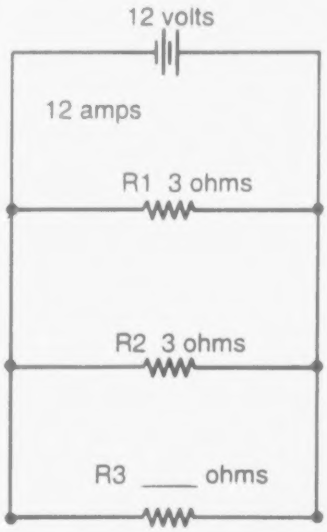
If you have more than one resistance, and you know all but one of these resistances, you can use Ohm's law to calculate the unknown resistance. In a series circuit, the resistance total (Rt) is equal to the sum of all the resistances.

In Figure 1, R1+R2+R3=Rt

Using Ohm's law, 12 volts divided by 2 amps of current flow would be 6 ohms of circuit resistance (Rt). You can then subtract R1 from R2 from Rt, or 6, to find that R3 equals 2 ohms of resistance.

Figure 2

In parallel circuits


12 volts
12 amps
R1 3 ohms
R2 3 ohms
R3 ____ ohms

In a parallel circuit, current can flow through more than one resistor at a time. In figure 2, current can pass through each resistance independent of every other resistance. If R1 opens, R2 and R3 will still flow current. Total circuit resistance is always less than the smallest resistance. Current flow in a parallel circuit is always greater than in a series circuit.

The formula for calculating resistance in a parallel circuit is as follows:

$$RT = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$

This formula can be used in any parallel circuit; it doesn't matter how many individual branches the circuit has.

Using the formula, let's calculate Figure 2.

First, calculate Rt, the resistance total.

12 volts/12 amps=1 ohm of total circuit resistance.

Now let's put what we know into the formula:
1/Rt = 1/R1 + 1/R2 + 1/R3.

1/1 or 1=1/3+1/3+1/R3
1=2/3+1/R3
1-2/3=1/R3
1/3=1/R3

So, resistance R3 is equal to 3 ohms of resistance.

You can verify that by calculating:

R1 uses 4 amps of current, R2 uses 4 amps of current, so if R3 equals 3 ohms of resistance, if would have 4 amps of current flow. So, 4 amps + 4 amps + 4 amps = 12 amps, which equals the number of amps flowing through the circuit.

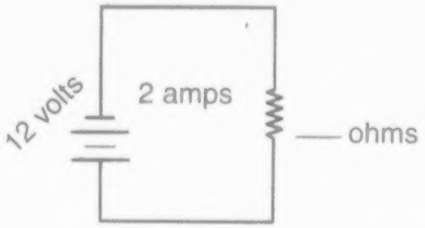
If you want to learn how to calculate resistance in series-parallel (complex) circuits, or if you still feel unsure how to calculate resistance in series or parallel circuits, go to the world wide web at:
>http://webhome.idirect.com/~jadams/electronics/spc_circuits.htm<

This site is an excellent source of information.

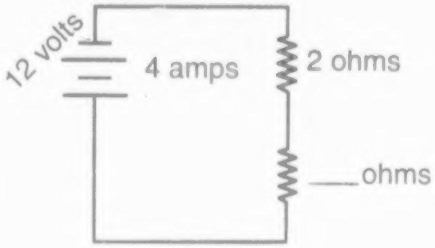
Assignment Sheet 4

Directions

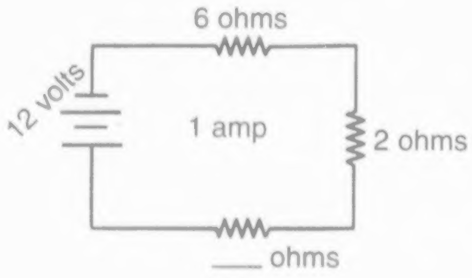
Calculate the unknown resistance in the following sample circuits. Write your answer in the space provided.


12 volts
2 amps
___ ohms

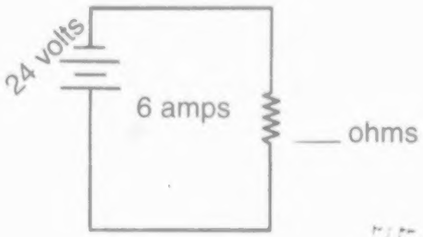
1. ______________________________


12 volts
4 amps
2 ohms
___ohms

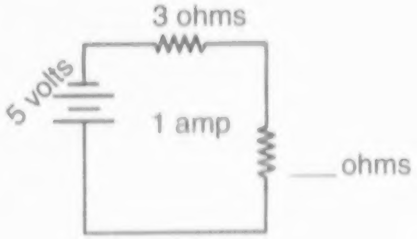
2. ______________________________


6 ohms
12 volts
1 amp
2 ohms
___ ohms

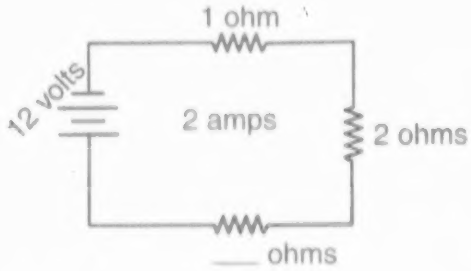
3. ______________________________


24 volts
6 amps
___ ohms

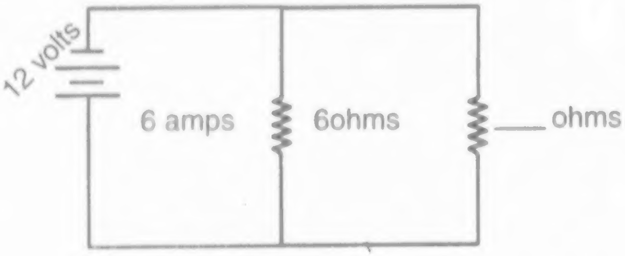
4. ______________________________


3 ohms
5 volts
1 amp
___ ohms

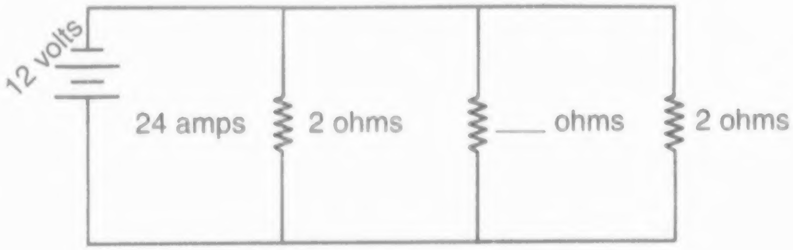
5. ______________________________


1 ohm
12 volts
2 amps
2 ohms
___ ohms

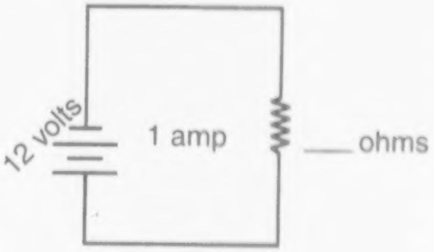
6. ______________________________


12 volts
6 amps
6ohms
___ ohms

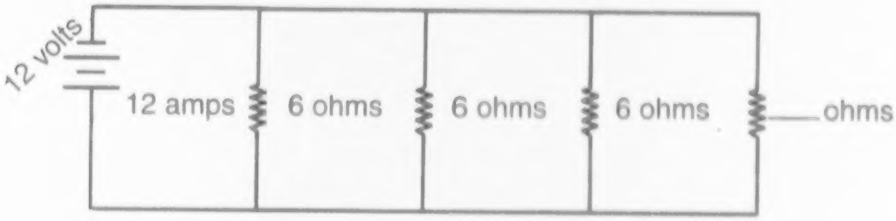
7. ______________________________


12 volts
24 amps
2 ohms
___ ohms
2 ohms

8. ______________________________


12 volts
1 amp
___ ohms

9. ______________________________


12 volts
12 amps
6 ohms
6 ohms
6 ohms
___ohms

10. ______________________________

759

Objective 12

Assignment Sheet 5—Calculate Current in Sample Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 5	______

Basic Skills

Reading Mathematics

Introduction

Having the ability to calculate current in a circuit is important to a technician. You can determine the size of circuit protection devices for a particular circuit. Using calculations of allowable current flow and comparing that to actual current flow can aid in diagnosing a circuit malfunction.

Ohm's law states that amperage is equal to voltage divided by resistance.

Amperage=voltage/resistance

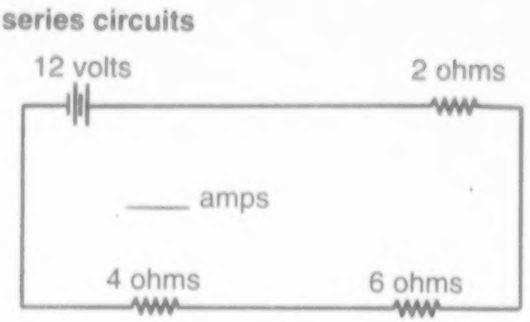
In simple or one-load circuits, calculating current is easy

Example

A circuit has 12 volts and 6 ohms of resistance. How much current is flowing through the circuit?

Amperage = 12 volts divided by 6 ohms of resistance
Amperage = 12/6
Amperage = 2

Figure 1

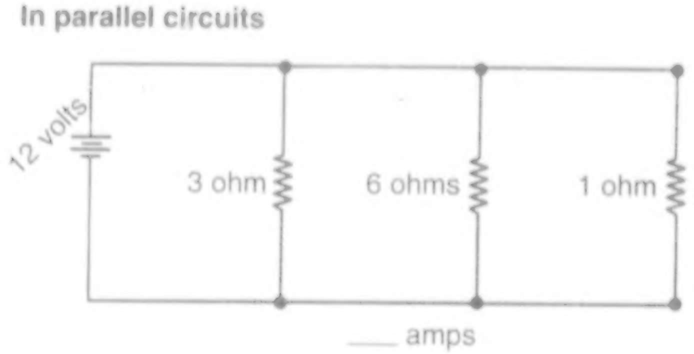


When the voltage and total circuit resistance (Rt) are known, calculating current flow in the circuit is a simple division problem. Remember that Rt (resistance total) is the sum of all circuit resistance, **Rt=R1+R2+R3**

In Figure 1, Rt = 2 + 4 + 6

After totaling the resistance, you will determine that Rt = 12. Then you simply divide the voltage, 12 volts, by Rt, 12 ohms, and calculate that the circuit current flow is 1 amp.

Figure 2



Calculating current in a parallel circuit is fairly easy. The total circuit amperage is the sum of the amperage of each individual branch of the parallel circuit.

In Figure 2, the amperage flowing through R1 is 4 amps because 12 volts divided by the 3 ohms of resistance of R1 equals 4 amps of current flow through R1. Amperage flow through R2 would be 2 amps (12 volts divided by 6 ohms), and amperage flow through R3 would be 12 amps (12 volts divided by 1 ohm). So the total circuit amperage draw would be 4 + 2 + 12 or 18 amps of current flow.

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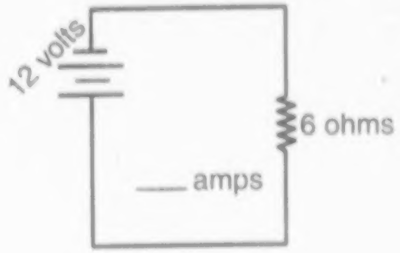
Assignment Sheet 5

If you want to learn how to calculate amperage in series-parallel (combination) circuits or if you still feel unsure how to calculate amperage in series or parallel circuits, go to the world wide web at >http://webhome.idirect.com/~jadams/electronics/spc_circuits.htm<

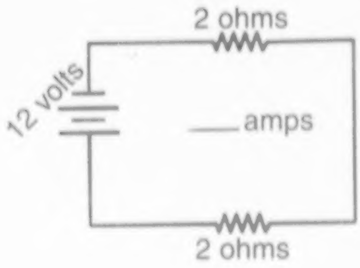
This site is an excellent source of information.

Directions

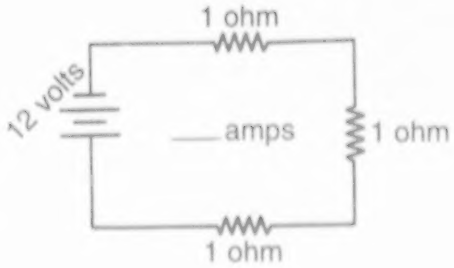
Calculate the unknown amperage in the following sample circuits. Write your answer in the space provided.


12 volts
6 ohms
___ amps

1. ______________________________

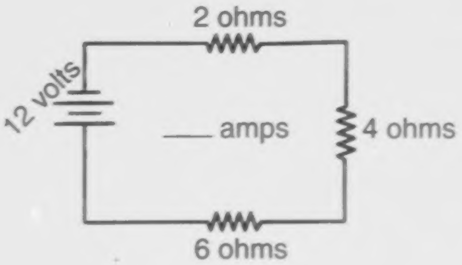

2 ohms
12 volts
___ amps
2 ohms

2. ______________________________

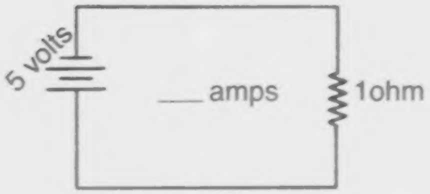

1 ohm
12 volts
___ amps
1 ohm
1 ohm

3. ______________________________

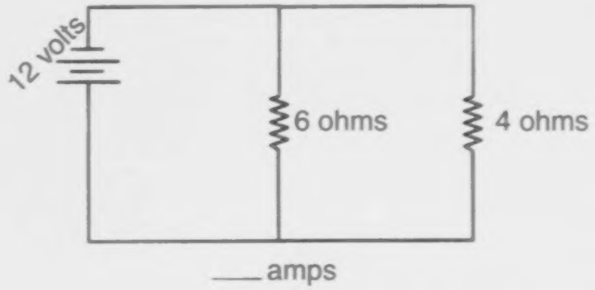
762


2 ohms
12 volts
___ amps
4 ohms
6 ohms

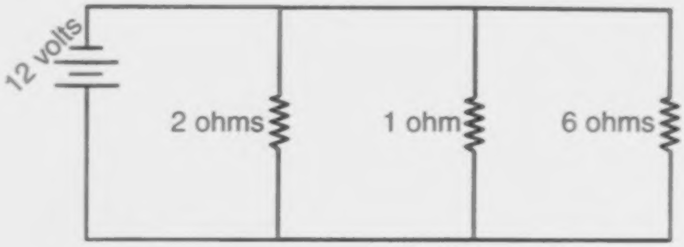
4. ______________________________


5 volts
___ amps
1ohm

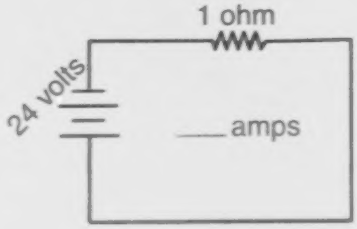
5. ______________________________


12 volts
6 ohms
4 ohms
___ amps

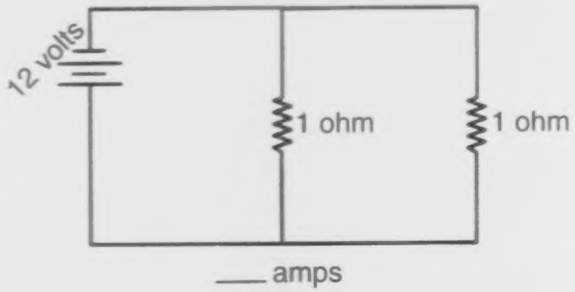
6. ______________________________


12 volts
2 ohms
1 ohm
6 ohms

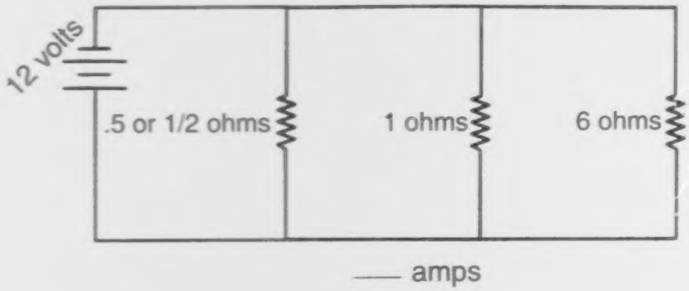
7. ______________________________


1 ohm
24 volts
___ amps

8. ______________________________


12 volts
1 ohm
1 ohm
___ amps

9. ______________________________


12 volts
.5 or 1/2 ohms
1 ohms
6 ohms
___ amps

10. ______________________________

Objective 13

Assignment Sheet 6—Calculate Voltage Drop in Sample Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 6	______

Basic Skills

Reading Mathematics

Introduction

Voltage drop is one of the better diagnostic tools to determine problems within an electrical circuit. The voltage drop of an entire circuit will always equal applied voltage. That is, the circuit will always use all of the voltage applied to the circuit. The more resistance a component of the circuit has, the more voltage will drop to allow amperage to flow through the component.

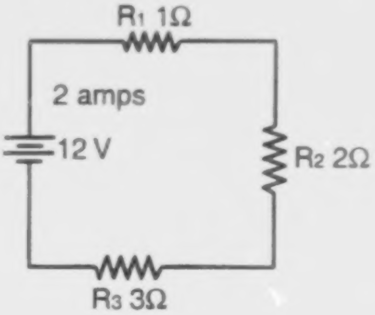
Voltage drop is very useful when testing connections, conductors, and control devices in the circuit. A connection should have very little or no resistance through it, so when you test a connection it should have very little or no voltage drop across the connection. Maximum allowable voltage drop across will vary slightly across a connection, but as a rule of thumb, .2 volts can be used as the maximum allowable voltage drop across a connection.

Conductors are the wires that connect the components of the circuit and allow electricity to flow. Generally the conductors should have little or no voltage drop through them. You should expect on any conductor that it would have a voltage drop of .1 volts or less. On control devices such as switches and relays, the connections made to allow electricity to flow are not solid connections, and since you do not have a solid connection, resistance of the connection is greater than it would be if it were a solid connection. You should use .5 volts as a maximum voltage drop across a control device.

In simple circuits, a 12-volt, 3-ohm of resistance, and 4-amp circuit, will use all of the voltage applied to the circuit, so the voltage drop of this circuit will be 12 volts. In a simple circuit, one-load circuit, voltage drop will always equal applied voltage.

Figure 1

In series circuits



In this circuit we know we have 12 volts of electrical pressure and the resistance total (Rt) is 6 Ohms (Rt - R1+R2+R3). To find the amperage we use Ohm's Law.

The formula is Amperage = Voltage/Resistance.

In this case 12 volts/6 Ohms equals 2 amps as given above. In a series circuit the amperage flowing in the circuit is the same through all the resistors. The amperage flowing through R3 is 2 amps, so to find the voltage drop of each load or resistor we must first know the amperage through the load—in this case 2 amps. We can use Ohm's Law to calculate voltage.

The formula is Voltage = Resistance X Amperage.

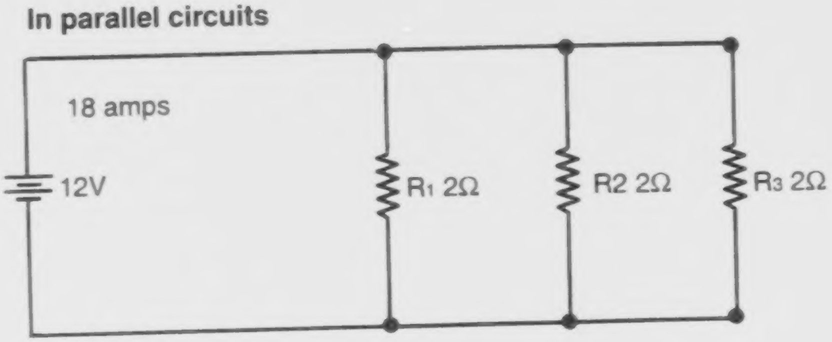
To calculate the voltage drop across R1, the equation would be:
Voltage = 1 Ohm x 2 Amps or Voltage = 2.

To calculate the voltage drop across R2, the equation would be:
Voltage = 2 Ohms x 2 Amps or Voltage = 4.

To calculate the voltage drop across R3, the equation would be:
Voltage = 3 Ohms x 2 Amps or Voltage = 6.

To check our answers we know that the sum of all the voltage drops equals the applied or source voltage. 2 + 4 + 6 = 12 volts, so our answer is correct.

Figure 2



Voltage drop in a parallel circuit is easy. Looking at figure 2, you can see that each resistor has the same amount of applied voltage, 12 volts, so the voltage drop of the individual resistor in a parallel circuit will always equal applied voltage.

Example

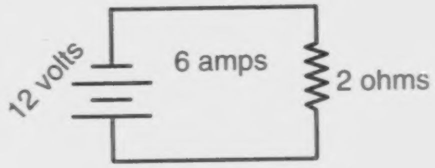
R1 = 12 volts of voltage drop
R2 = 12 volts of voltage drop
R3 = 12 volts of voltage drop

If you want to learn how to calculate voltage drop in series-parallel (combination) circuits or if you still feel unsure how to calculate voltage drop in series or parallel circuits, go to the world wide web at >http://webhome.idirect.com/~jadams/electronics/spc_circuits.htm<.

This site is an excellent source of information.

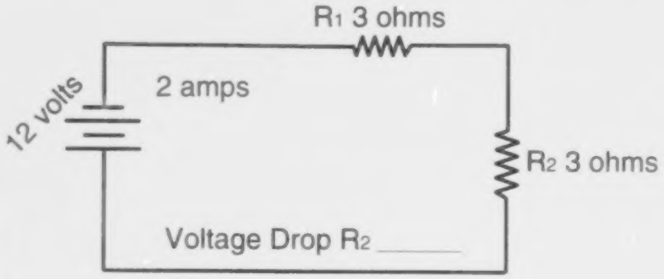
Directions

Calculate voltage drop in the following sample circuits. Write your answer in the space provided.

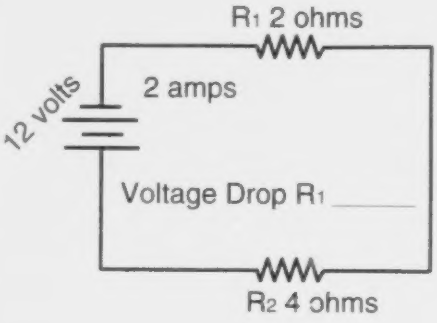


1. ____________________

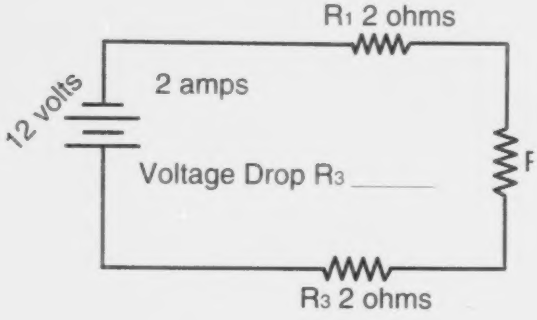
767


R₁ 3 ohms
12 volts
2 amps
R₂ 3 ohms
Voltage Drop R₂ ______

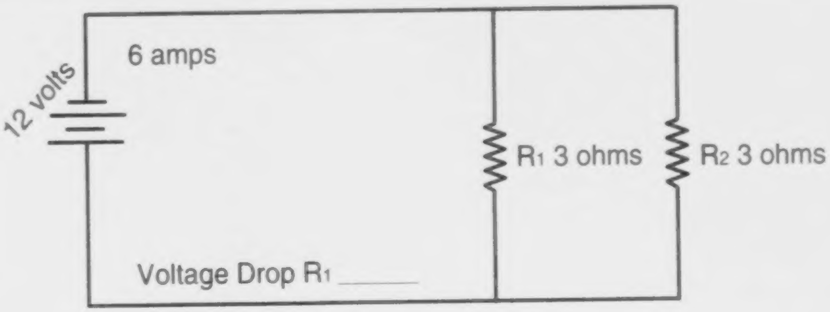
2. ____


R₁ 2 ohms
12 volts
2 amps
Voltage Drop R₁ ______
R₂ 4 ohms

3. ____

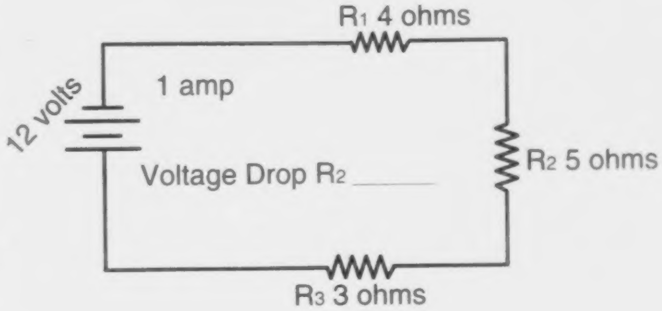

R₁ 2 ohms
12 volts
2 amps
Voltage Drop R₃ ______
R₃ 2 ohms

4. ____


12 volts
6 amps
R₁ 3 ohms
R₂ 3 ohms

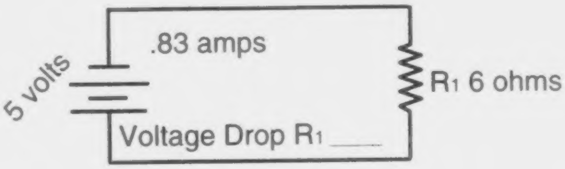
Voltage Drop R₁ ______

5. ____


R₁ 4 ohms
12 volts
1 amp
R₂ 5 ohms
R₃ 3 ohms

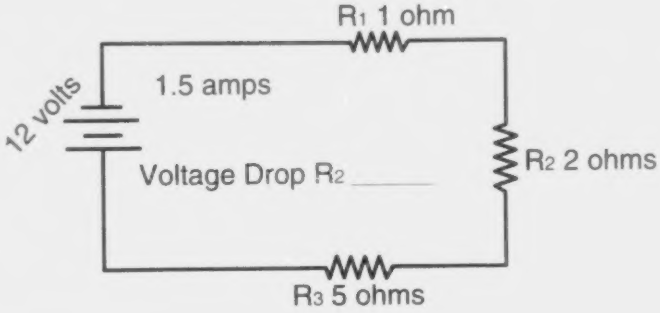
Voltage Drop R₂ ______

6. ____


5 volts
.83 amps
R₁ 6 ohms

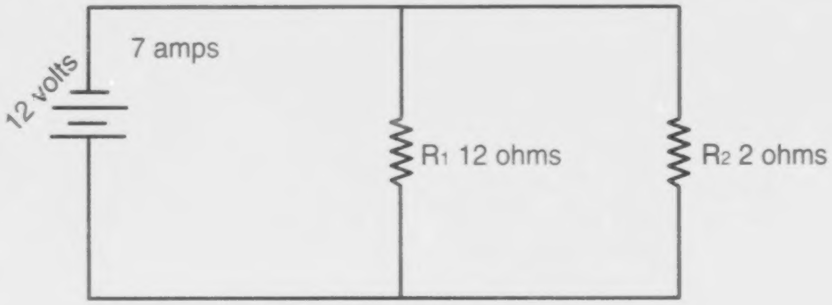
Voltage Drop R₁ ____

7. ____


R₁ 1 ohm
12 volts
1.5 amps
R₂ 2 ohms
R₃ 5 ohms

Voltage Drop R₂ ______

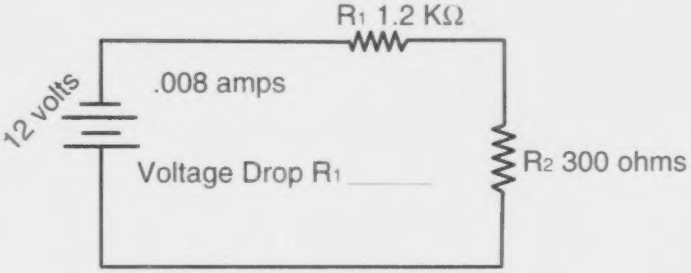
8. ____



12 volts
7 amps
R1 12 ohms
R2 2 ohms

Voltage Drop R_1 _____

9. ____



R1 1.2 KΩ
12 volts
.008 amps
Voltage Drop R1 _____
R2 300 ohms

10. ____

770

Objective 14

Assignment Sheet 7—Calculate Voltage in Sample Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 7	______

Basic Skills

Reading Mathematics

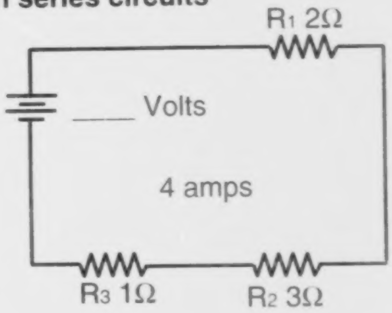
Introduction

In most cases you won't have to calculate voltage to repair a circuit. Generally you will have to measure and compare to specifications. Calculating voltage is a simple enough task using Ohm's law. Ohm's law states that voltage is equal to resistance multiplied by amperage. You must realize that to use Ohm's law in series and parallel circuits, you must use the total circuit resistance (Rt).

In simple circuits, if a circuit has 3 amps of current flow and 4 ohms of circuit resistance, simply multiply resistance by current. In this example the circuit voltage is 12 volts.

Figure 1

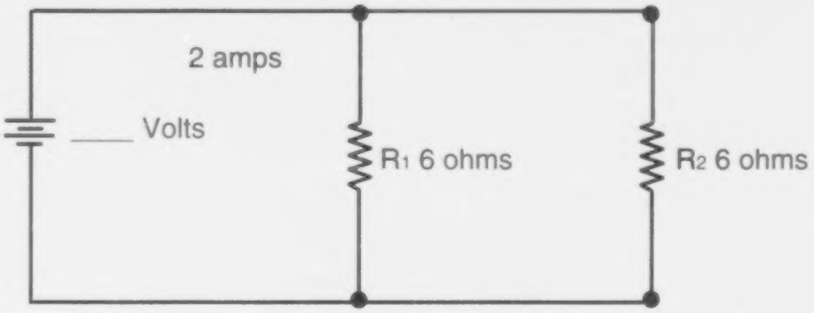
In series circuits



In a series circuit, the Rt is the sum of the individual resistances. Simply add R1 (2 ohms), R2 (3 ohms) and R3 (1 ohm). Doing this shows that total circuit resistance equals 6 ohms of resistance (2+3+1=6). Then multiply the 4 amps of current flow by the 6 ohms of Rt. This calculates to 24 volts of pressure in the Figure 1 circuit.

Figure 2

In parallel circuits



Calculating the total circuit resistance (Rt) in a parallel circuit is different than calculating it in a series circuit. Remember the formula from Assignment Sheet 4, $1/Rt = 1/R1 + 1/R2 + 1/R3$Ö.

Let's use our formula to calculate Rt for Figure 2.

$1/Rt = 1/6 + 1/6$
$1/Rt = 2/6$
$1/Rt = 1/3$
$Rt = 3$

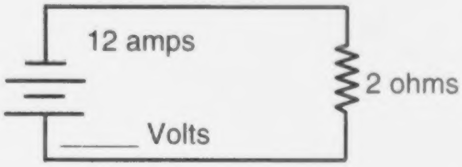
Now let's take the 2 amps flowing through the circuit and multiply it by the 3 ohms of total circuit resistance. This means that 6 volts of pressure are pushing the 2 amps of current flow through the two 6 ohm branches of the circuit.

If you want learn how to calculate voltage in series-parallel (combination) circuits or if you still feel unsure how to calculate voltage in series or parallel circuits, go to the world wide web at
>http://webhome idirect.com/~jadams/electronics/spc_circuits.htm<.

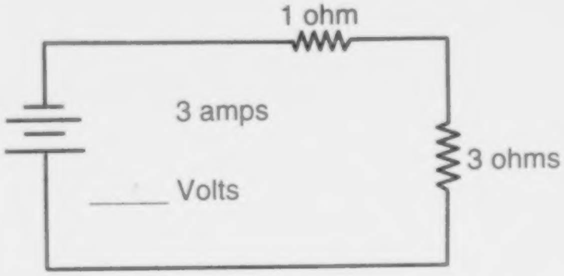
This site is an excellent source of information.

Directions

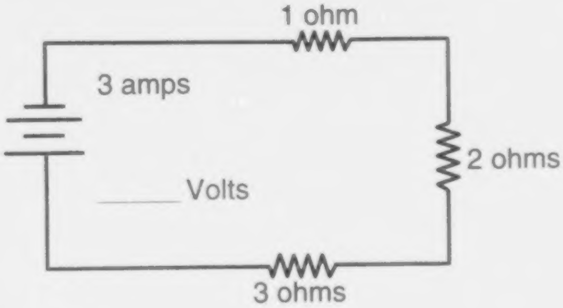
Answer the unknown voltage in the following sample circuits. Write your answer in the space provided. Round answers to the nearest .5 volt.



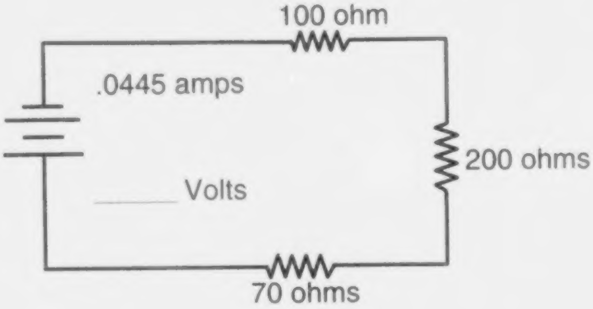
1. ____________________


1 ohm
3 amps
3 ohms
____ Volts

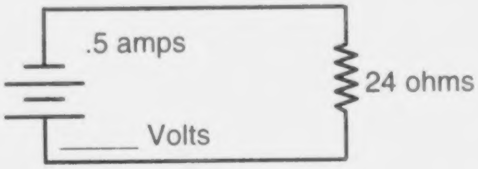
2. ________________________________


1 ohm
3 amps
2 ohms
____ Volts
3 ohms

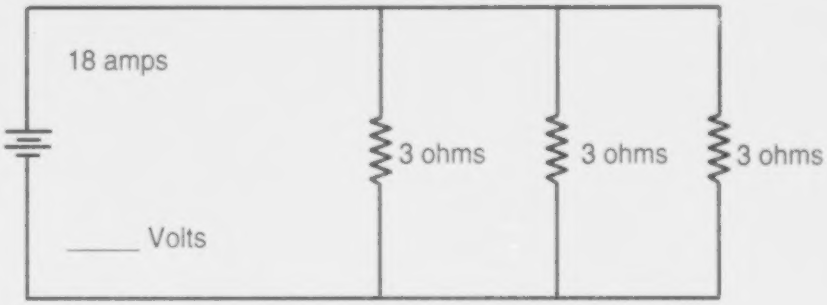
3. ________________________________


100 ohm
.0445 amps
200 ohms
____ Volts
70 ohms

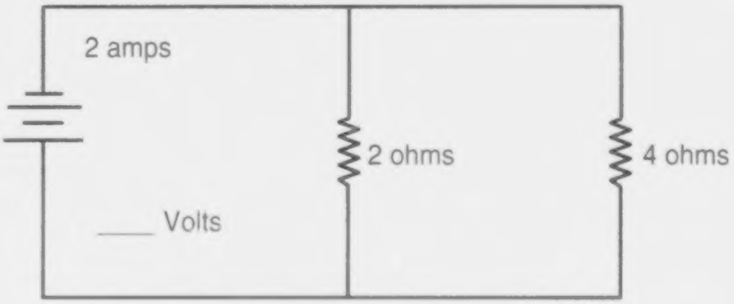
4. ________________________________


.5 amps
24 ohms
____ Volts

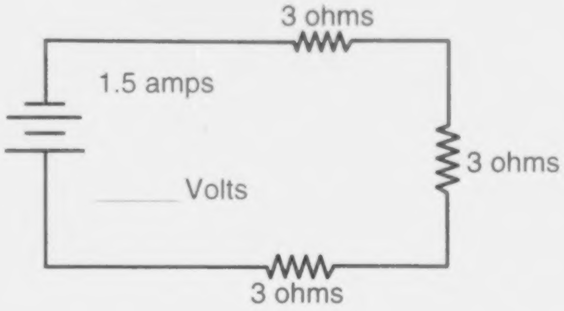
5. ________________________________


18 amps
3 ohms
3 ohms
3 ohms
_____ Volts

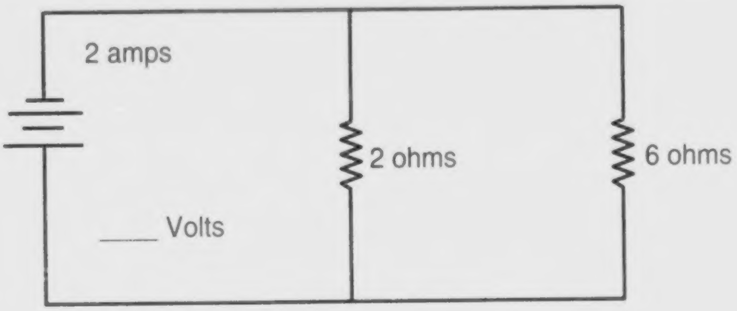
6. ____


2 amps
2 ohms
4 ohms
____ Volts

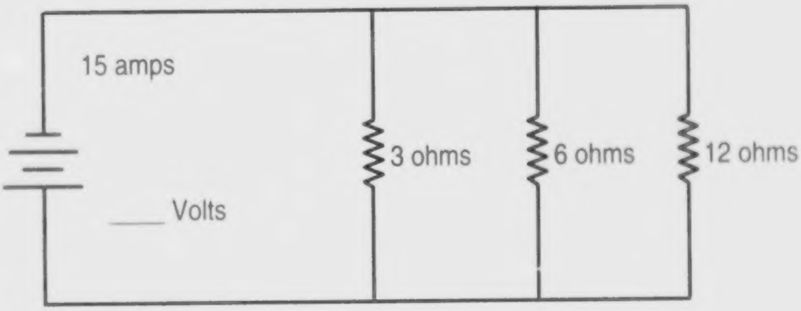
7. ____


3 ohms
1.5 amps
3 ohms
______ Volts
3 ohms

8. ____


2 amps
2 ohms
6 ohms
____ Volts

9. ______________________________


15 amps
3 ohms
6 ohms
12 ohms
____ Volts

10. ______________________________

775

Objective 15

Job Sheet 1—Calibrate and Make Functionality Tests on Electrical Diagnostic Instruments

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability Technology

Introduction

Electrical diagnostic instruments use very accurate measurements to check the operation of electrical components and circuits. In order to make measurements within the degree of accuracy needed, the instruments must first be calibrated or tested to make sure the instrument gives a true and precise reading.

As technology advances, sophisticated equipment and instruments will continue to explode upon the market. It is important to always follow both manufacturer's instructions for the vehicle and the equipment used to test it.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Electrical diagnostic instruments
- Safety glasses
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedures in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

______________________ ______________________

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 16

Job Sheet 2—Check Electrical/Electronic Circuits With Jumper Wires

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

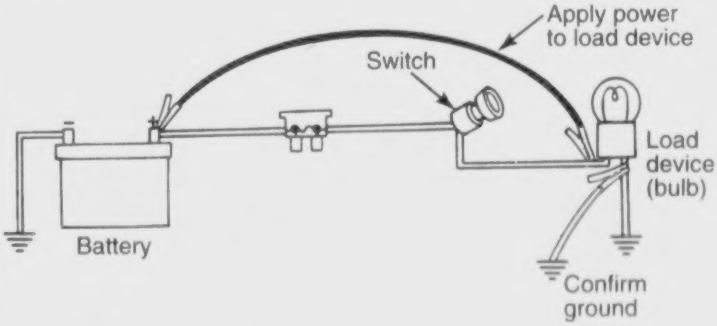
Basic Skills

Reading   Critical Thinking   Employability

Introduction

Jumper cables are heavy electrical cables with large terminal clamps at each end used to start a vehicle with a discharged battery. Jumper wires can also be used to test for continuity. By using the wires to bypass a portion of a circuit, the status of that load can be determined. A jumper wire creates a temporary parallel circuit. If a short or ground has occurred in the "jumped" portion, the circuit will travel the jumper wire and complete the circuit.

Figure 1



Jumper wires can be equipped with the same type of probes and clips found on continuity testers, and can also be fitted with specialized connectors and terminals for specialized testing.

Job Sheet 2

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Booster power supply
- Jumper wires
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

> Warning: Never connect a jumper wire across the terminals of the battery. This will cause a direct battery short, and may result in a battery exploding, causing serious injury and/or fire.

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Connect a jumper wire bypassing a portion of the circuit to be tested.

☐ 8. Connect the other wire to the load to be tested.

- If the load does not work, that portion of the circuit is malfunctioning and must be repair or replaced.
- If the load does work, that portion of the circuit is OK. Working back up the circuit from the load devices, continue to test until the problem is isolated.

☐ 9. Determine needed repairs.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ________________________________

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Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 17

Job Sheet 3—Check Electrical Circuits With a Test Light

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

There are basically three types of test lights available—a *6 volt*, *12-volt*, and *self-powered test light*. A **6- or 12-volt test light** is used to test circuits while electrical current is flowing through them. They're used for voltage-seeking and ground-seeking tests. The voltage-seeking test indicates whether voltage is present in the circuit at a particular point. The ground-seeking test indicates whether or not a conductor, switch, or other unit is grounded. These two lights depend upon the vehicle's battery to power the circuit under test. Most test lights have a sharp probe on the end of them. However, some test lights have special tips better suited to properly fit terminals, bare wires, insulated wires, or even wires within wiring harnesses. If you puncture wire insulation to insert a test light, be sure to repair the insulation. If you don't, the conductor will corrode and create resistance in the circuit.

Note: Be sure you know the voltage of the system you are working on. Using a 6-volt test light on a 12-volt system will cause the light to blow. If you use a 12-volt test light on a 6-volt system, the bulb may not light, giving you false test results.

Self-powered test lights, like the ohmmeter, are designed for use in circuits that have been disconnected from the battery. The self-powered test light checks for *continuity* in circuits and electrical components. The continuity of a circuit refers to current that flows from the power source to the electrical components and back to the power source as designed. A *quick check* with a self-powered test light will establish the presence or absence of continuity.

The self-powered test light uses a low voltage battery (1.5 volts) light and test leads. The test light is connected to the circuit in *series*. The portion of the circuit being checked must be disconnected so voltage is **not** present. The self-powered test light is ideal for checking for open circuits, grounds, and shorts.

Job Sheet 3

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- 12-volt test light
- Safety glasses
- Self-powered test light
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Check for voltage in a circuit with a 12-volt test light

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Attach the test light lead to a known circuit ground.

☐ 8. Attach the other test light lead or probe to a portion of the circuit.

- If the light glows, it indicates the presence of voltage at that point in the circuit. The more intense the light, the more amount of voltage is present.
- A dim light indicates low voltage.
- If the light does not light, it indicates an open circuit.

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☐ 9. Move the test light successively back up the circuit toward the battery until the light glows. The open part of the circuit is then between the last point probed and the point where the light glows.

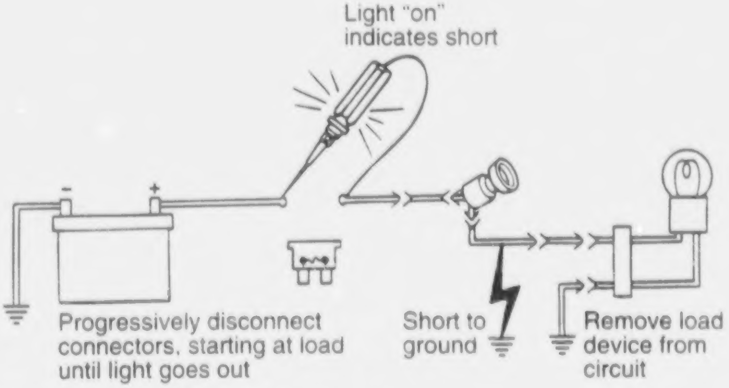
Check for shorts to ground in a circuit with a 12-volt test light

☐ 1. Substitute the test light for the blown fuse to limit the current flowing in the circuit.

- If the light glows with all the load devices in the circuit disconnected, it indicates a short to ground.

☐ 2. Disconnect connectors in the circuit working back up the circuit from the load devices until the test light goes out. The short is located between the disconnected connector and the previously disconnected connector.

Figure 2


Light "on"
indicates short
-
+
Progressively disconnect connectors, starting at load until light goes out
Short to ground
Remove load device from circuit

Used with permission of DaimlerChrysler Corp.

☐ 3. Turn in job ticket when finished.

☐ 4. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 4—Check Voltage in Electrical/Electronic Circuits with a Multimeter

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading

Critical Thinking

Employability

Introduction

The *voltmeter* function of a multimeter is used to measure the electrical pressure or the voltage difference between two points. It is typically used to measure available voltages in the battery, alternator, or voltage drop across a component or conductor. It can also be used to locate an open circuit.

When the test leads are connected to the circuit, the voltage causes a small amount of current to flow through the meter. The higher the voltage, the greater the current. Therefore, the current flowing in the meter is an indication of the amount of voltage that caused it to flow.

Many voltmeters have more than one range. Whenever you use a voltmeter, start on the highest range to prevent damage to the meter. When the voltmeter is connected into the circuit, switch down to a range that will allow an accurate reading. The readings are most accurate in the upper portion of the meter scale.

Multimeters vary from manufacturer to manufacturer. Do not try to use a multimeter without reading and understanding the operator's manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Multimeter
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Job Sheet 4

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Select a voltmeter operating range that is higher than the voltage being measured.

☐ 8. Ground the negative voltmeter lead to a known grounding point. Attach the positive lead to a point in the circuit where you want to read voltage. Available voltage will be indicated on the voltmeter.

☐ 9. Locate damaged parts.

☐ 10. Determine needed repairs.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

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Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 19

Job Sheet 5—Check Voltage Drops in Electrical/Electronic Circuits With a Multimeter

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

The *voltmeter* part of the multimeter is used to test and measure voltage drops. The difference in this type of measurement to that of a voltmeter measuring voltage is in the way the voltmeter is connected to the circuit. To check for voltage drop, use a voltmeter connected between the points where the voltage drop is to be measured. When checking voltage drop, current must be flowing in the circuit.

Wiring must have low enough resistance values to allow enough voltage to the load for proper operation. Maximum allowable voltage loss due to voltage drops across wires, connectors, and other conductors in a circuit is 10% of the system voltage. Therefore, in a 12-volt automotive electrical system the maximum total loss is 1.2 volts.

Multimeters vary from manufacturer to manufacturer. Do **not** try to use a multimeter without reading and understanding the operator's manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Safety glasses
- Voltmeter/multimeter
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Job Sheet 5

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Set the voltmeter to its highest DC voltage scale, then move down in scale until you get the best reading.

☐ 8. Test the voltage drop of the entire circuit, connect the positive lead to the positive terminal of the battery. Connect the negative lead to the power wire at the connector for the load.

☐ 9 Turn on the circuit. Read the voltmeter, if there are no unwanted resistance in the circuit, the voltmeter will read less than 0.1 volt. If the reading is greater than 0.1 volt, wire or connector problems are indicated. To find the source of the problem, move the negative test lead to another circuit connector closer to the battery.

☐ 10. Locate damaged parts.

☐ 11. Determine needed repairs.

☐ 12. Turn in job ticket.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

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Job Sheet 5

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________________

Supervisor ____________________

Objective 20

Job Sheet 6—Check Current Flow in Electrical/Electronic Circuits and Components With a Multimeter

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

The *ammeter* part of the multimeter is used to measure the amount of current in a circuit in amperes. Conventional ammeters are connected in series with the circuit by actually opening the circuit and allowing current to pass through the ammeter. Inductive or long-type ammeters are slipped over the outside of the wire insulation and use the magnetic field around the wire to determine amperes.

Before making a current measurement, set the ammeter to its highest current range. Apply voltage to the circuit and switch down to a range that will allow an accurate reading. The readings are most accurate in the upper portion of the meter scale.

Multimeters vary from manufacturer to manufacturer. Do **not** try to use a multimeter without reading and understanding the operator's manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Ammeter/Multimeter
- Safety glasses
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Job Sheet 6

Note: Procedures vary with the vehicle. Always check the procedures in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Clip the ammeter leads into the circuit, observing correct test lead polarity.

☐ 8. Apply voltage to the circuit and note the meter reading.

☐ 9. Turn power off to the circuit, disconnect the ammeter, and restore the original circuit connection.

- If you get a reading of zero amps, either the circuit is open or the power is not on.
- If you get a current draw reading higher than specifications, a short circuit to ground or a short which bypasses the load exists.
- If you get a current draw reading which is lower than specification, there is either too much resistance in the system or a low available voltage condition exists.

☐ 10. Locate damaged parts.

☐ 11. Determine needed repairs.

☐ 12. Turn in job ticket.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 21

Job Sheet 7—Check Continuity and Resistance in Electrical/Electronic Circuits and Components With a Multimeter

Name ________________ Attempt Number ______

Date ________________ Overall Rating ______

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

The *ohmmeter* function of the multimeter measures resistance to current flow in electronic circuits and devices. It is commonly used to measure ignition coil resistance, secondary ignition wire resistance and all types of semiconductor resistance. The ohmmeter is battery-driven and does not rely upon voltage available in the circuit. When power is on in the circuit it will damage the ohmmeter. Do not use an ohmmeter on any solid-state components in the circuit, as damage may occur.

The two leads of the ohmmeter are connected in parallel with the circuit or component being tested. The meter sends current through the component and determines the amount of resistance based on the voltage dropped across the load. As the resistance gets larger, the current flow gets smaller. Thus, as the resistance gets smaller, more current will flow through the ohmmeter.

The scale of an ohmmeter reads from zero to infinity. A zero reading means there is no resistance in the circuit, indicating no measurable resistance, which is often referred to as continuity. An infinity reading usually means an open circuit. A reading in-between zero and infinity is the component's actual resistance to current flow.

Multimeters vary from manufacturer to manufacturer. Do **not** try to use a multimeter without reading and understanding the operator's manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 7

Tools, equipment, and materials

- Ohmmeter/multimeter
- Safety glasses
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 6. Mark the circuit with a colored pen or highlighter.

☐ 7. Isolate conductor or load device from the circuit by disconnecting it.

☐ 8. Calibrate the ohmmeter by touching the two leads together. Adjust the calibration knob to zero. Hold the leads apart. The scale should indicate infinity.

☐ 9. Touch the leads to the terminals of the circuit to be tested.

Note: It is **not** necessary to observe test lead polarity if the circuit is open.

☐ 10. Disconnect the load or component to be tested from the circuit.

☐ 11. Choose a multiplier scale which corresponds as specified by the service manual.

☐ 12. Multiply the reading on the scale by the setting on the multiplier scale.

☐ 13. Locate damaged parts.

☐ 14. Determine needed repairs.

☐ 15. Turn in job ticket.

☐ 16. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 22

Job Sheet 8—Find Shorts, Grounds, Opens, and High Resistance Problems in Electrical/Electronic Circuits

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

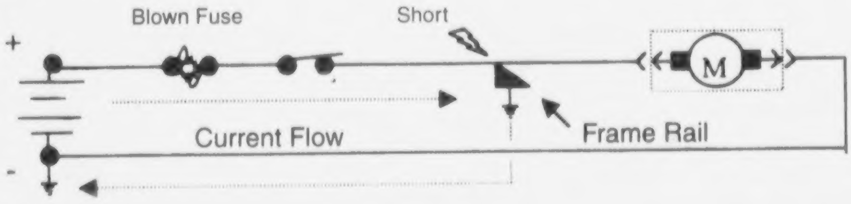
Reading Critical Thinking Employability

Introduction

A short occurs when the positive side of the circuit comes in contact with a ground source or stray voltage. Failed conductors, terminals, or insulation causes shorts. One way to isolate a short is to check voltage along the circuit with an ammeter. (Increased electrical current may indicate a short.)

Figure 1

Short to Ground



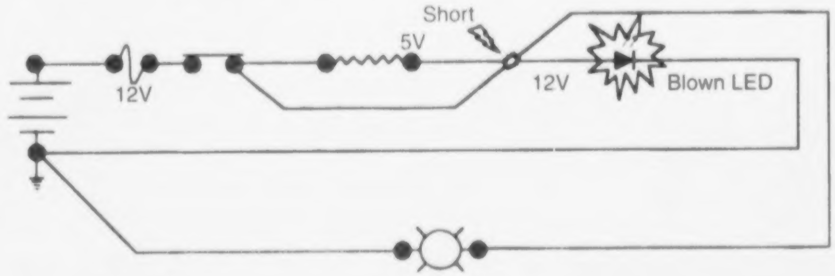
If shorted to ground, the current will take the path of least resistance. There will be no current between the short and the normal circuit ground. If the short is between the protection device and circuit device, the fuse or circuit breaker protecting the circuit should "blow" due to the high current flow to the short. If the short is between the power source and protection device, the conductor will "burn" back to the power source and could cause a fire.

If one path in a parallel circuit is grounded, the other path(s) will continue to receive normal power. A ground in a series circuit will prevent any part of the circuit from receiving power.

One way to locate a ground is to substitute a 6- or 12-volt test light for the circuit's fuse to limit the current flowing in the circuit. Connectors in the circuit can then be disconnected, working back up the circuit from the load devices until the test light goes out. The short to ground is located between the disconnected connector and the previously disconnected connector.

Figure 2

Short to Stray Voltage



If shorted to voltage, both circuits will now carry the higher voltage of the two circuits. Any circuit device that is not designed to operate off this higher voltage will be damaged. If the circuit device is capable of handling the higher voltage, it is certain that it will not operate as designed.

Open circuits occur when switches are open or some other break occurs in the circuit, preventing current from passing through the circuit. An open circuit can be intentional or unintentional. Blown fuses, fusible links, or open circuit breakers result in open circuits, as do loose connections and broken wires. When a series circuit is open, no part of the circuit will receive power. In a parallel series, the path containing the open circuit will receive no power, but all other paths will. An ohmmeter or voltmeter can be used to diagnose an open circuit. If the voltmeter is used, connect the negative lead to ground and the positive lead to the circuit. If voltage registers, no open has occurred between that point and the source. Remember that the circuit must be receiving power when the measurement is taken. By moving the positive lead along the circuit, the site of the open can be discovered. An ohmmeter can be used in a similar manner. If resistance is high, continuity is poor.

Loose or badly corroded connections increase the resistance in a circuit. These may result in reduced current, or may, in extreme cases, appear to be an open circuit. All loads in a circuit are affected by *high resistance*. Using improper wire gauge may also cause high resistance, although this is not likely.

High resistance problems are sometimes the most difficult to trace. Since these commonly involve problems with grounding, first follow the steps described above for testing for grounds. If the problem persists, follow the directions in the appropriate service manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 8

Tools, equipment, and materials

- Jumper wires
- Ohmmeter, voltmeter or multimeter
- Self-powered test light
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility.
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedures in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate the appropriate service manual. Use the index to locate the schematic drawing that diagrams the affected system. Make a copy of the diagram.

☐ 2. Use the symbols key in the front of the manual to help you understand the diagram. Read through the diagram until you have traced the entire circuit.

☐ 3. Mark the circuit with a colored pen or highlighter.

☐ 4. Complete the accompanying job ticket with all pertinent information.

☐ 5. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 6. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 7. Turn off the vehicle, remove the keys, and close the doors.

☐ 8. Open the hood and locate the battery.

☐ 9. Locate the affected circuit

☐ 10. Check for continuity (finding open circuits).

- Disconnect the circuit from the battery.
- Connect one lead of a self-powered test light or ohmmeter to each end of the circuit.
- If the light comes on or if resistance is low, the circuit has no open circuits.

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☐ 11. Check for shorts and grounds.

- Locate the fuse in the affected circuit.
- Remove power from all circuits powered through the fuse. Turn off or disconnect circuits, disconnect motor connectors and remove light bulbs.
- Power fuse (usually by turning the ignition switch to on).
- Test for power in the circuit. Connect one test light lead to ground and the other to the end nearest the battery of the blown fuse. The light should come on.
- Disconnect test light lead attached to ground and attach it to load side or end farthest from battery of fuse.

  ☐ **If the test light is off,** the short is in the disconnected equipment. Test each load by connecting it to the circuit then jumping it with a jumper wire. If the circuit runs when jumped, the load is bad.

  ☐ **If the test light goes on,** the wiring contains the short. One at a time, disconnect, then reconnect, circuit connectors. If the light goes out, the short is probably not in that area. If the light stays on, the circuit is shorted, allowing the open to be bypassed. Inspect the area between the last two disconnected circuit connectors.

☐ 12. Check for high resistance problems.

- With circuit powered, connect a voltmeter to the suspected bad ground and frame. Any detected voltage may indicate a bad ground and high resistance fault.
- With circuit under powered, connect a self-powered test light or ohmmeter to the suspect wire and to a good ground. If low resistance is indicated, the ground is good.

☐ 13. Determine needed repairs.

☐ 14. Turn in job ticket.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

8.1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name __________

Address __________

Phone # __________

Date In __________

Date Out __________

JOB TICKET

Customer Name __________

Customer Address __________

Customer Phone # __________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: __________

Services/repairs made: __________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

__________ Date __________

Technician __________

Supervisor __________

Job Sheet 8

Objective 23

Job Sheet 9—Tin a Soldering Iron or Gun

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Procedures followed accurately	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Safety glasses
- Soldering iron or gun (with replaceable tips)
- Solder, rosin-core on roll
- Clean, damp cloth or sponge
- Technician's common hand tools
- Safety glasses

Procedure

Note: Before a tip is used, it must be tinned—coated with a very thin film of solder.

> Caution: Follow all shop safety procedures. Wear safety glasses.

☐ 1. Before plugging in, inspect tip for proper wedge shape.

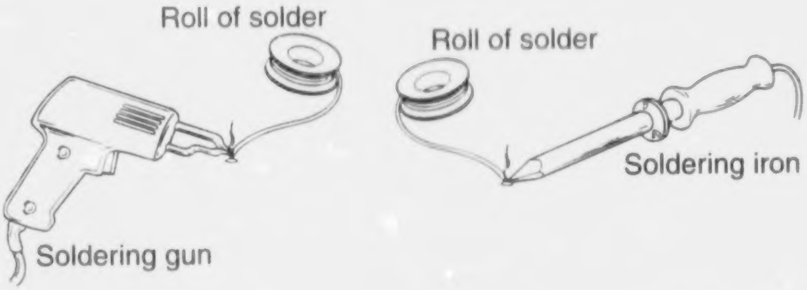
☐ 2. If tip is **not** properly wedge-shaped, check with your instructor to determine proper shaping procedure, and shape tip, removing as little metal as possible.

Note: Most tips can be shaped with file; however, irons and guns with iron-clad tops should **not** need reshaping. Normally, iron-clad tips are merely cleaned with a wire brush. Filing will shorten their useful life. Gold-plated tips are very expensive and should **never** be filed.

☐ 3. Place soldering iron/gun in holder, connect power cord to power receptacle, and allow iron/gun to heat.

☐ 4. Apply small amount of rosin-core solder directly to the tip.

Figure 1



☐ 5. Shake the tip slightly to remove excess solder.

☐ 6. Use a clean damp cloth or sponge to wipe off the soldering iron/gun after use.

> Caution: Keep iron/gun over cloth on work surface. Hot solder dripping from the soldering iron/gun can burn your skin or damage you clothing.

☐ 7. Disconnect power cord from power receptacle, place iron/gun in holder, and allow to cool.

☐ 8. Have instructor inspect soldering tip.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Objective 24

Job Sheet 10—Inspect, Test, Repair, and Replace Switches, Connectors, Terminals, and Wires of Electrical/Electronic Circuits

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

The type of repair required and the ease of access to the damaged area are a few of the factors to consider when removing and replacing faulty components. The type of conductor, size of wire, circuit requirements and manufacturer's recommendations are also factors to consider.

You should never add to a circuit, remove part of a circuit, change the size of a circuit protection device, or the size of a conductor without first consulting with the manufacturer. Department of Transportation laws affect how certain circuits should be constructed and how they should perform.

Conductors break for many reasons. Excessive motion, stress, and excessive current flow are all conditions that eventually lead to insulation breakdown or breakage. The most common methods of wire repairs include heat shrinking, crimping the terminals with solderless terminals, and soldering splices.

Electrical tape should not be used to splice wires or repair insulation. Over time, tape will come loose, crack, rot, and fall away allowing the connection to corrode and cause high resistance. At best, the use of electrical tape should only be considered a temporary repair. Crimped terminals are considered a temporary repair if they're not insulated properly. Improper insulation will allow dirt and solvents to enter the connection causing corrosion and resulting in high resistance or an open circuit.

Soldering is the most effective method to splice wires. Solder is an alloy of tin and lead that is melted over a splice to hold the wire ends together. Rosin core solder cleans the wire surface allowing solder to flow around and stick to the wire. **Never use acid core solder because it will cause the solder connection to corrode**. Soldering may be a splicing procedure, but it is also an art that takes much practice.

Heat shrinking is an effective method to insulate a splice, terminal, or broken wire insulation. Heat shrink is a plastic tube that will shrink to a smaller size when heated. Single wall heat shrink is just plastic tubing and should be used only inside a vehicle. Double wall heat shrink has an outer plastic tube coated internally with resin (the second wall). When the tube is heated and shrinks around the wire, it also melts the resin which seals off the outer tube and the insulation of the wire. The heat shrink tube should be cut a quarter inch longer on each end to overlap and seal against the wires' insulation. There are a wide variety of sizes of heat shrink.

When testing a switch, use a jumper wire to bypass the switch. A switch is defective and needs to be replaced if the circuit is not working *before* the jumper is used, and working when the jumper *is* used. Do not use the jumper wire to bypass the load component; the high current will damage the circuit. Voltage drop across switches should also be checked. When the switch is closed, there should be no voltage drop. Any voltage drop indicates resistance, and the switch should be replaced.

A voltmeter or test light can be used to check for voltage on both sides of the switch. A faulty switch would have voltage present at the input side of the switch but not on the output side when in the "On" position.

Testing with an ohmmeter requires the removal of the switch. With the switch contacts opened there should be no continuity between the terminals. When the contacts are closed, there should be zero resistance through the switch contacts. On complex ganged-type switches, the technician should consult the service manual for a continuity diagram. If there is no continuity chart, use the wiring diagram to make your own chart.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Soldering gun
- 60/40 rosin core solder
- Continuity light
- Crimping tool
- Heat shrink
- Ohmmeter
- Splice clip
- Switches to be tested
- Assorted terminals
- Wire stripping & crimping tool
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Student Supplements 3 & 4
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Wire repair or replacement

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disconnect the battery

☐ 6. Remove the wiring harness protective covering to expose the damaged wire, if necessary.

☐ 7. Cut off any damaged sections of wire.

☐ 8. Strip one inch of insulation from each end of the wire using wire strippers.

☐ 9. Slide a piece of heat shrink tubing over the end of the wire. Make sure that the tubing will be long enough to cover and seal the repair areas.

☐ 10. Twist the wires together.

☐ 11. Solder the wires together using rosin core solder.

☐ 12. Center the heat shrink tubing over the joint and heat using a heat gun until sealant flows from both ends of the tubing.

☐ 13. Secure the wiring and install the wiring harness protective covering to prevent chaffing or damage to the insulation.

Connector repair or replacement

☐ 1. Disconnect the battery.

☐ 2. Disconnect the connector that is to be repaired from its mating half. (Refer to Student Supplement 4)

☐ 3. Remove connector locking wedge.

☐ 4. Position the connector locking finger away from the terminal. Pull on the wire to remove the terminal from the connector.

☐ 5. Reset the terminal locking tang, if it has one.

☐ 6. Insert the removed wire in the same cavity on the repaired connector.

☐ 7. Repeat steps 4 through 6 for each wire in the connector, being sure that all wires are inserted into the proper cavities. For additional connector pin-out identification, always refer to the wiring diagrams.

☐ 8. Insert the connector locking wedge into the repaired connector.

☐ 9. Connect connector to its mating half.

☐ 10. Connect battery and test all affected systems.

Installing a solderless terminal

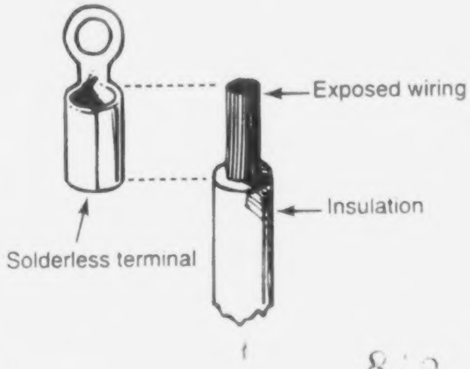
☐ 1. Determine wire gauge.

☐ 2. Select terminal to match wire gauge.

☐ 3. Test-strip insulation from wiring until insulation is removed without damaging exposed wiring.

☐ 4. Strip insulation from end of wire to expose enough wiring to permit installation of terminal.

Figure 1



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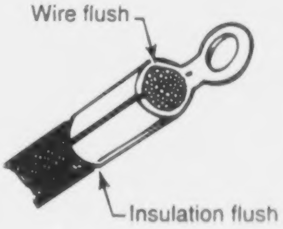
☐ 5. Test-fit wiring in terminal

Note: The insulation on the wire should be cut so that it will butt squarely against the terminal and be stripped to a length so that the exposed wiring will enter the terminal completely. If the insulation does not butt squarely, it should be recut, and if too much has been removed, the wiring should be trimmed.

Figure 2



☐ 6. If necessary, correct cut and trim wire.

☐ 7. Clean exposed wiring on small-gauge wire (16-gauge or smaller) with cleaning-flux solution; clean larger-gauge wiring by carefully scraping with a razor blade.

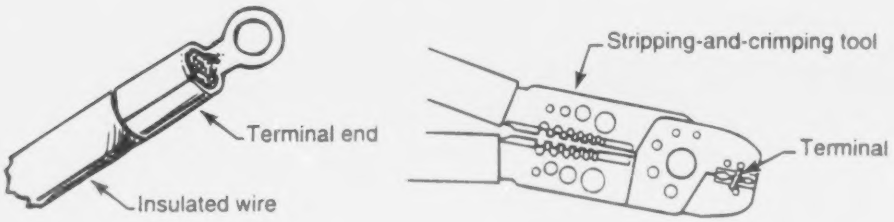
Caution: Take care not to cut or nick the wiring (or yourself).

☐ 8. If using heat-shrink insulation, cut and slide insulation onto conductor.

☐ 9. Clean terminal with sandpaper.

☐ 10. Place exposed wiring into terminal, and form crimped connection using crimping area of wire-stripping-and-crimping-tool.

Figure 3



☐ 11. Test crimped connection by pulling on the wire.

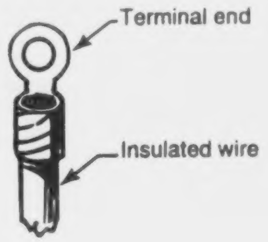
Note: You should **not** be able to pull the wire out of a good crimped connection.

☐ 12. If crimped connection is secure, have instructor check connection.

☐ 13. Insulate crimped connection by applying heat to heat-shrink insulation.

Note: Use a heat gun to apply heat to heat-shrink insulation. Do not use a match. A match creates too much heat, which will make the tubing brittle and cause it to crack.

Figure 4



Installing a soldered terminal

☐ 1. Following previous steps 1 through 12 for installing a solderless terminal.

☐ 2. Prepare soldering-iron or -gun tip for use. (See Job Sheet 9)

☐ 3. Plug soldering-iron or -gun power cord into power receptacle and allow to heat.

☐ 4. If using heat-shrink insulation, cut and slide insulation onto conductor.

Note: Slide tubing back far enough on the conductor to keep it from heating during the soldering process.

☐ 5. When iron or gun is hot, heat exposed wiring and apply rosin-core solder to crimped connection, applying only enough solder to attach terminal or connector securely.

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Warning: Do not build up solder on crimped connection. The connection will break if too much solder is applied. Do not move the connection until the solder has hardened and cooled. Moving the connection before the solder cools may break the connection.

☐ 6. Test cooled and hardened connection by attempting to pull connection apart by hand.

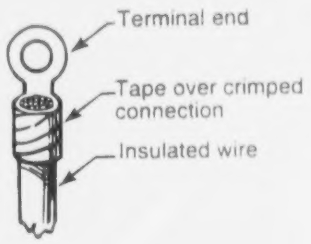
☐ 7. If connection seems loose, reheat wire to melt solder more thoroughly and retest when solder cools.

☐ 8. When connection is secure, have instructor inspect cooled and hardened soldered connection.

☐ 9. Insulate solder connection by applying heat to heat-shrink insulation.

Note: Use a heat gun to apply heat to heat-shrink insulation. Do not use a match. A match creates too much heat, which will make the tubing brittle and cause it to crack.

Figure 6



☐ 10. Have instructor inspect insulated connection.

Switch repair or replacement

☐ 1. Connect the ohmmeter to the switch being tested.

☐ 2. Place switch in the off or open position.

☐ 3. Check for an ohmmeter reading of infinite resistance.

☐ 4. Place switch in the on or closed position.

☐ 5. Check for an ohmmeter reading of zero resistance.

☐ 6. Accept if all of the above conditions are met; otherwise, reject or replace the switch.

☐ 7. Repeat steps 1 through 6 for each switch tested.

☐ 8. Use the continuity light in place of the ohmmeter and repeat steps 1 through 7; check for continuity in the on or closed position.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________________

Technician ____________________

Supervisor ____________________

Job Sheet 10

Objective 25

Job Sheet 11—Inspect, Test, and Replace Fusible Links, Circuit Breakers, and Fuses

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Critical Thinking Employability

Introduction

By knowing which circuit is receiving excessive current or how often fuses are blown, the technician can target testing to pinpoint the circuit fault. A fusible link, circuit breaker or fuse that is undersized will blow quickly; if one allows too much current, it may lead to a short or fire.

Fusible links and circuit breakers require more testing and more involved replacement procedures. Unlike fuses and fusible links, circuit breakers are not replaced when they blow. Testing circuit breakers for current will help pinpoint the source of a problem. In some cases, circuit breakers must be reset.

A fusible link is four wire-gauges smaller than the cable it protects, even though it appears much larger. The thicker insulation is a safety feature. There are two types of insulation used on fusible links: Hypalon® and Silicone/GXL (SIL/GXL). Hypalon® cannot be used to replace a link made with SIL/GXL, but SIL/GXL can be used to replace either type. To determine the fusible link type, nick the insulation of the blown link. If the insulation core is the same color as the outer shell, it is Hypalon®; if the core is white and the shell is another color, it is SIL/GXL. As with any replacement procedure, follow safety rules.

When replacing any protective device, be sure the proper size replacement is used.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 11

Tools, equipment, and materials

- Crimping tool
- Electrical tape
- Fusible links
- Knife
- Ohmmeter, voltmeter or multimeter or self-powered test light
- Replacement fuses
- Replacement fusible links
- Solder tools and solder
- Wire strippers
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility.
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Fuses

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Locate fuse blocks

☐ 6. Lift out fuses one at a time from the fuse block.

☐ 7. Visually inspect each fuse as it is removed. A blown fuse will have a broken element and should be replaced.

☐ 8. Connect a test light to ground and to either side of the fuse. If one side shows poor, replace the fuse. If both sides show poor, energize the circuit and repeat.

☐ 9. Determine the proper size of replacement fuse. Replacement fuses must be of the correct rating to protect the system.

☐ 10. Replace blown fuse.

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Job Sheet 11

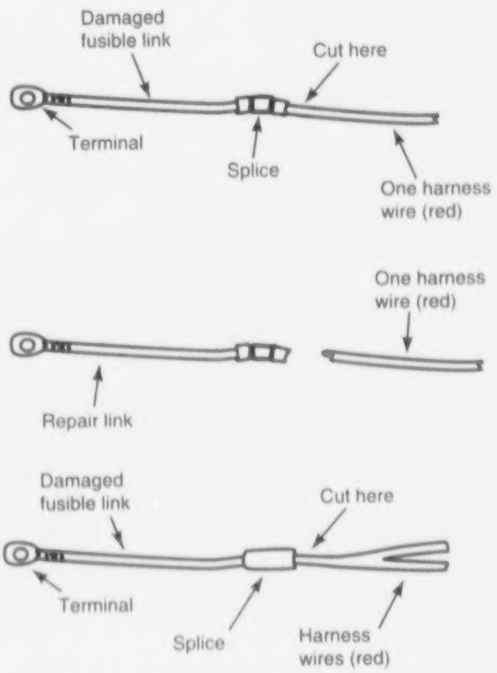
Fusible links

☐ 1. Use the service manual to locate fusible links.

☐ 2. Determine if voltage is continuing through the fusible link by connecting a voltmeter or test light to a good ground and to the lead past the fusible link. If the light comes on or the voltmeter registers current, the link is intact. If no current registers, the link has blown and should be replaced.

☐ 3. Remove the blown link by cutting it off beyond the splice. If the link feeds two harness wires, cut them both off beyond the splice and use two repair links. Make certain that each splice is at least 1.5 inches from other splices, branches, or connectors.

Figure 1


Damaged fusible link
Cut here
Terminal
Splice
One harness wire (red)
One harness wire (red)
Repair link
Damaged fusible link
Cut here
Terminal
Splice
Harness wires (red)

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☐ 4. Select the proper replacement link.

Note: Remember, do not replace Silicone/GXL with Hypalon®.

☐ 5. Determine the length of the link. Choose the shortest usable length.

Note: A fusible link should never be more than nine inches in length.

☐ 6. Use the wire strippers to strip insulation from the fusible link and from the lead it will be connected to.

☐ 7. Test wiring and link for proper fit in connector and adjust stripping as necessary.

☐ 8. Inspect stripping job on lead and on link for damage to wire.

☐ 9. Cut and slide heat shrink onto conductor.

☐ 10. Select the proper connecting clip.

☐ 11. Hold the overlapped wires between thumb and forefinger (see diagram). Center the splice clip under the wires.

☐ 12. Open the crimping tool, resting one handle on a flat surface.

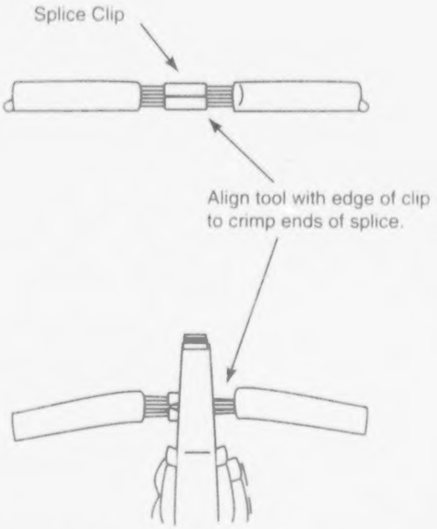
☐ 13. Place the splice clip on the proper anvil, centering the back of the clip.

☐ 14. Close the crimping tool until the splice clip is held firmly but not crimped.

☐ 15. Inspect the clip and wires again. Be sure the wires are not damaged, stripped wires extend from each end of the clip, and no insulation is under the clip.

☐ 16. Crimp the splice by applying a steady, firm pressure to the crimping tool.

Figure 2



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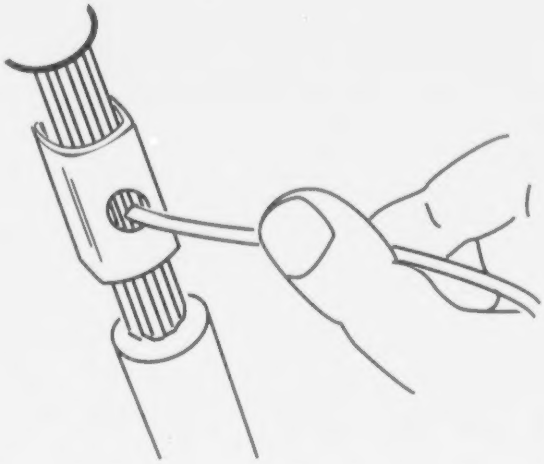
☐ 17. Apply a 60/40 rosin core solder to the opening in the back of the clip.

Figure 3



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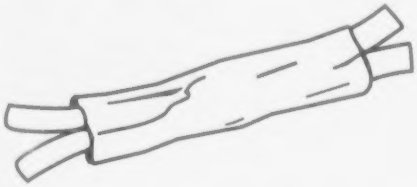
☐ 18. Insulate crimped connection by applying heat to heat-shrink insulation.

Note: Use a heat gun to apply heat to heat-shrink insulation. Do not use a match. A match creates too much heat, which will make the tubing brittle and cause it to crack.

Figure 4



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Circuit breakers

☐ 1. Use the service manual to locate circuit breakers.

☐ 2. Connect an ohmmeter to the circuit breaker and ground, following instructions for use.

☐ 3. Place the circuit breaker in the off or open position.

☐ 4. Check for an ohmmeter reading of infinite resistance.

☐ 5. Place circuit breaker in the on or closed position.

☐ 6. Check for an ohmmeter reading of zero resistance.

☐ 7. Accept if all of the above conditions are met; otherwise, reject or replace the circuit breaker.

- If the circuit breaker is blown, it will show full resistance or no voltage.
- If the circuit breaker is blown, locate the reset opening.

☐ 8. Insert a small wire in the opening and push against the spring tension.

☐ 9. Test again with ohmmeter.

☐ 10. Use the continuity light in place of the ohmmeter and repeat steps 3 through 5, checking for continuity in the on or closed position.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Unit 4 Understanding Vehicle Computer Controls

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2—How Information Travels Among Sensors, Computers, and Actuators 4–19
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2—Access Vehicle Fault Codes Using the Vehicle's Computerized Diagnostic System; Determine Needed Repairs 4–49

Unit 4 Understanding Vehicle Computer Controls

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify the components and describe the functions of a vehicle computer system, demonstrate how a potentiometer functions as a sensor, and retrieve and analyze fault/trouble codes. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match the terms related to vehicle computer controls to their definitions.
2. Match the basic components of a computer system to their functions.
3. List common vehicle computers (microprocessors).
4. Distinguish among types of sensors.
5. Distinguish among types of actuators.
6. Distinguish between analog and digital signals.
7. Distinguish between serial data transfer and parallel data transfer.
8. Trace the flow of data through a simplified computer system.
9. List ways to retrieve diagnostic information from vehicle computers.
10. Break down SAE fault code identifiers and differentiate between the three number groups.
11. Demonstrate how a potentiometer functions as a sensor. (Assignment Sheet 1)
12. Interpret SAE fault code identifiers. (Assignment Sheet 2)
13. Use a DVOM to measure reference voltage output from the electronic control module. (Job Sheet 1)
14. Access vehicle fault codes using the vehicle's computerized diagnostic system; determine needed repairs. (Job Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **Binary Code**—A simple language based on a two-digit numbering system expressed as 0 and 1, on and off, or high and low; the "language" that a computer uses to "think".

b. **Data line/link**—The communication link between other on-the-vehicle and off-the vehicle computers and diagnostic tools.

c. **Microprocessor**—Computer chips or integrated circuits that use binary code to analyze data and determine what should be done

d. **Program**—A detailed set of instructions that guide the computer's response to input signals

e. **Trouble/fault code**—A number code that corresponds to a malfunction identified by the computer

Objective 2

Functions of the basic components of a computer system

Note: Computers perform four basic jobs: (1) receive input signals, (2) process input signals (follows a decision-making process based on programmed instruction), (3) store information, and (4) send output signals (based on decisions made) (Figure 1). The input device sends a voltage signal to the microprocessor. The microprocessor logic circuits use the input information, calculates, and measures them against programmed instructions. After the computer has made a decision, various output devices are sent signals that correct or maintain the system being monitored.

a. **Microprocessor (computer)**—made up of integrated circuits that are capable of making intelligent decisions within the guidelines of programmable instructions.

   Example: The microprocessor will receive an input (analog/voltage) signal from a sensor, turn it into a digital (binary code) signal, compare it to programmed instructions, make changes by sending a digital signal that is converted back to a analog signal (voltage), and send it (output) to a specific actuator that makes mechanical changes to the vehicle system being monitored.

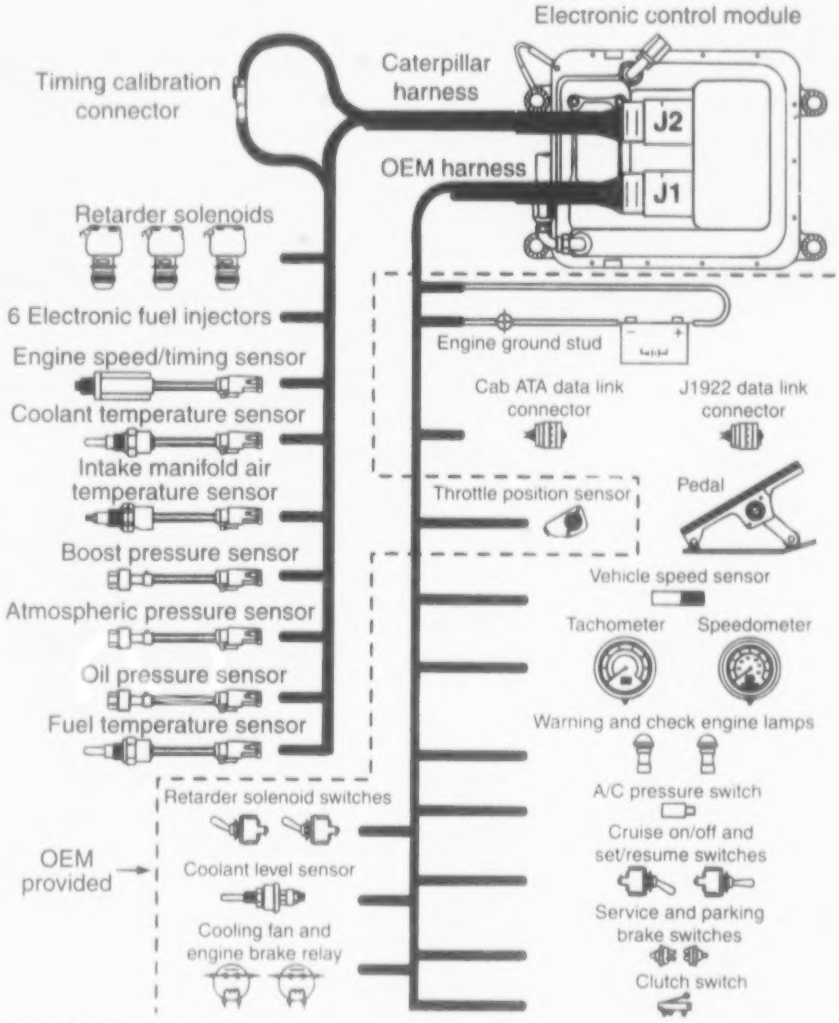
b. **Sensor (input)**—a component that gathers information about vehicle operations, converts that information into voltage signals, and sends it to the computer as input.

   Examples: A sensor converts mechanical movement, such as position, pressure, or temperature, into electrical signals (voltage). For example, a potentiometer can be used to send a variable voltage signal from a fuel level or throttle pedal sensor. Switches are the simplest sensors (because they only have two positions; open or closed).

c. **Actuator (output)**—a component that performs a task in response to an output signal; converts computer output signals (voltage) into mechanical action.

Example: Actuators can be solenoids, relays, or motors. The computer controls output in three ways. It (1) internally switches to a positive voltage, which is sent to load device that is grounded all the time, (2) internally switches to "ground," which is sent to a load device that has positive voltage all the time, or (3) sends a pulse width modulated (duty cycle) signal to a load device that is grounded all the time (this will vary the load device's mechanical movement).

Figure 1


Electronic control module
Timing calibration connector
Caterpillar harness
J2
OEM harness
J1
Retarder solenoids
6 Electronic fuel injectors
Engine speed/timing sensor
Coolant temperature sensor
Intake manifold air temperature sensor
Boost pressure sensor
Atmospheric pressure sensor
Oil pressure sensor
Fuel temperature sensor
Engine ground stud
Cab ATA data link connector
J1922 data link connector
Throttle position sensor
Pedal
Vehicle speed sensor
Tachometer
Speedometer
Warning and check engine lamps
A/C pressure switch
Cruise on/off and set/resume switches
Service and parking brake switches
Clutch switch
Retarder solenoid switches
Coolant level sensor
Cooling fan and engine brake relay
OEM provided

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Objective 3

Common computers (microprocessors) in a vehicle

Use a service manual or other publication to locate the following computers on a vehicle. First, locate the computers on figures and diagrams. Next, locate the same computers on an actual vehicle. List any additional computers that are not listed here.

- Airbag control module
- Antilock brakes and traction control module
- Antitheft/security system module
- Climate control module
- Engine control module
- Transmission control module
- Transmission control module
- Alarm/Indicator module
- Remote keyless entry module
- Trip information module
- Collision/Perimeter warning module
- Ground position/Communication module
- Rollover protection module
- Instrumentation control module
- ______________________________
- ______________________________
- ______________________________

> Warning: Serious damage to the Electronic Control Module and its components may result from welding if all connections are not disconnected. If the hotshot charging system must be used when the microprocessor is connected, then it should be powered by an isolated battery not connected to the hotshot.

Objective 4

Types of sensors

Sensors are input devices. They convert physical conditions, such as position or temperature, into electrical signals (voltage). Read Supplement 2. Use a service publication or a manufacturer's CD-ROM to locate sensors on a vehicle. First, locate the sensors on figures and diagrams. Next locate them on an actual vehicle, if possible.

a. **Magnetic pulse generator**—a magnetic induction device that produces an AC voltage signal to sense speed of the monitored component

Examples: antilock brake, vehicle speed sensor

b. **Potentiometer**—a variable resistor that senses mechanical movement and changes it into a variable voltage signal to the computer

Examples: throttle position sensor, level control sensor, fuel level sensor

c. **Switch sensor**—opens or closes the circuit and can sense almost any condition

Example: coolant level sensor

d. **Thermistor**--a resistor that varies voltage based on changes in temperature

Note: A thermistor measures voltage drop through a voltage-sensing circuit. Its electrical resistance decreases or increases with changes in temperature. The voltage drop readings are translated into a temperature value by comparing the voltage reading measurements to the computer's programmed values.

Examples: engine temperature sensor, oil temperature sensor, air temperature sensor

e. **Capacitance (pressure) sensor**—uses a variable capacitor made of a positive and negative plate attached to electronic circuitry to sense pressure

Note: In a capacitance sensor, the computer supplies a reference voltage to the sensor. Electronic circuitry measures the capacitance of the variable capacitor and sends a signal back to the computer.

Examples: oil pressure sensor, fuel pressure sensor

f. **Wheatstone bridges**—A series-parallel arrangement of resistors that sense pressure, temperature, and mechanical strain

Note: A wheatstone bridge is usually made up of four resistors. Three resistors are held to the same value; the fourth resistor changes when conditions change. When all four resistors have the same value, the bridge is balanced. When the fourth resistor changes with condition changes, the sensing circuit receives a voltage reading that is proportional to the amount of resistance change.

Examples: Turbo boost sensor, barometric pressure sensor, manifold absolute pressure (MAP) sensor

g. **Hall-effect sensor**—uses motion to generate frequency signals as an input to monitor commonly controlled parameters

Note: The Hall-effect sensor operates on the principle that if a current is allowed to flow through thin conducting material that is exposed to a magnetic field, another voltage will be produced. The sensor produces a signal with a low frequency when the vehicle is moving at a relatively low speed. As speed increases, the sensor generates a signal with a higher frequency.

Examples: Camshaft position sensor, timing reference sensor, crankshaft or engine position sensor

Objective 5

Types of actuators

Note: The computer can control output in three ways: it can (1) apply steady voltage, (2) apply ground, or (3) vary voltage through pulse width modulation, frequency, or duty cycle.

a. **Relay**—controls high-current circuits to protect the computer

Example: The computer energizes the relay to actuate the door lock motor. Actuating the door lock switch applies low current or ground to the relay coil. The circuit generally contains two relays: one for the locking sub-circuit and one for the unlocking sub-circuit. With the switch in the LOCK position, the energized coils in the relay shifts between one of two positions. Current flows through the locking relay to each of the motors or solenoids to engage the locking mechanism. The ground leg of the circuit runs through the unlocking relay. With the switch in the UNLOCK position, the relay coils energize and shift to the opposite position, allowing current to flow in the opposite direction. This reverses the direction of movement in the motors or solenoids, while current flows back through the locking relay to ground. Often the locking and unlocking relays are one integrated module.

b. **Solenoid**—changes electric current into mechanical motion

Note: The computer usually controls the ground connection to the solenoid. A solenoid is an electromagnetic device with a moveable iron core (attached to a mechanical linkage) that can be used to close large electrical contacts or to engage parts. A solenoid may push or pull the core into the coil. For example, a push-pull solenoid in the electric door lock system uses a permanent magnet core and proper polarity to put the field in opposition. When current flows to the core, it moves the linkage of the door to lock or unlock it.

c. **Motor**—changes electric current into mechanical motion

Note: The computer usually controls the ground connection to the motor. A stepper motor has a permanent magnet armature with two, four, or more field coils. It applies voltage pulses to selected coils of the motor in order to move the controlled device to whatever location that is desired. A feedback sensor signals the computer to stop current flow to the motor when it is in the desired location.

d. **Visual warning device**—changes electric current into visual energy

Note: The computer usually controls the ground connection to the lamp. It allows current to flow from a power source through the lamp element back to the ground source inside the computer. This activates the warning assembly.

e. **Audible warning device**—changes electric current into audible energy

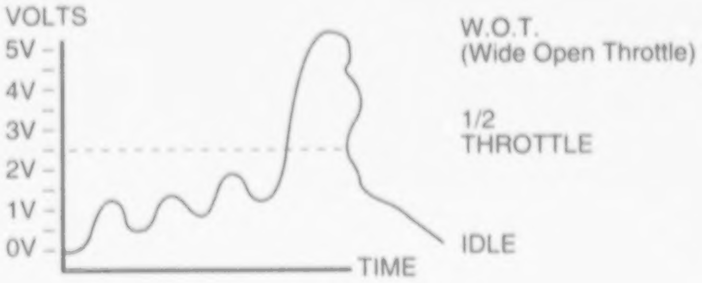
Note: The computer sends a modulated pulse width signal to an alarm that is always grounded. The pulsating variable voltage signal actually makes the different sounds of many alarms.

Objective 6

Analog and digital signals

a. **Analog**—a voltage signal that is continuously variable within a certain voltage range (Figure 2)

Figure 2



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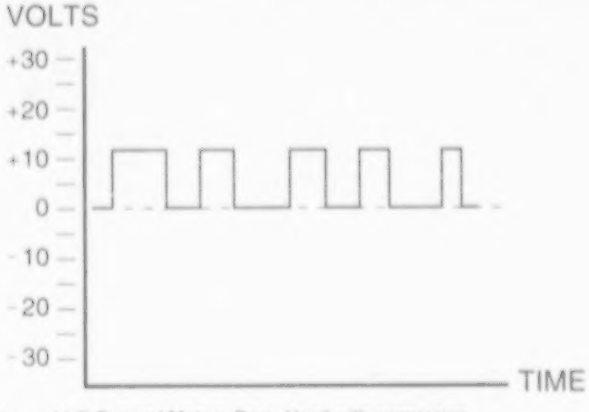
b. **Digital**—a voltage signal that has only two possible measurements (on or off, high or low, yes or no, etc.); called a square wave (Figure 3)

Figure 3



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Note: Analog signals are usually produced by sensors. The microprocessor can process only digital (binary) voltage signals. An input interface converts the analog signal from the sensors to the digital signal needed by the microprocessor (the analog-to-digital or A/D interface). An output interface converts the digital signal back into an analog signal for those actuators that require analog signals (the digital-to-analog or D/A interface).

Objective 7

Serial data transfer and parallel data transfer

Note: One computer communicates with another by sending a digital signal along a data line/link. Two ways in which this communication takes place are serial data transfer and parallel data transfer.

a. **Serial Data Transfer**—the transfer of data between computers one byte (digital "word") after the other in one direction (Figures 4 and 5)

Figure 4

COMPUTER 1
DATA LINK
COMPUTER 2

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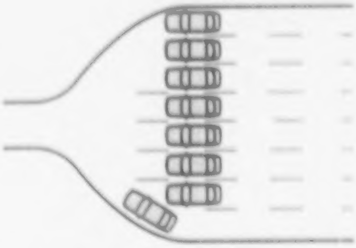
Figure 5



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b. **Parallel Data Transfer**—the transfer of each element of the data at the same time on its own data line (Figures 6 and 7)

Figure 6

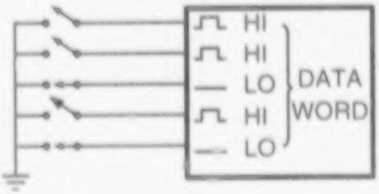

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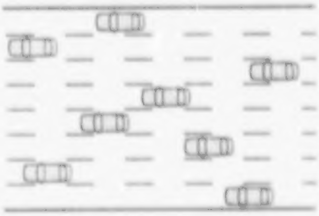
Figure 7



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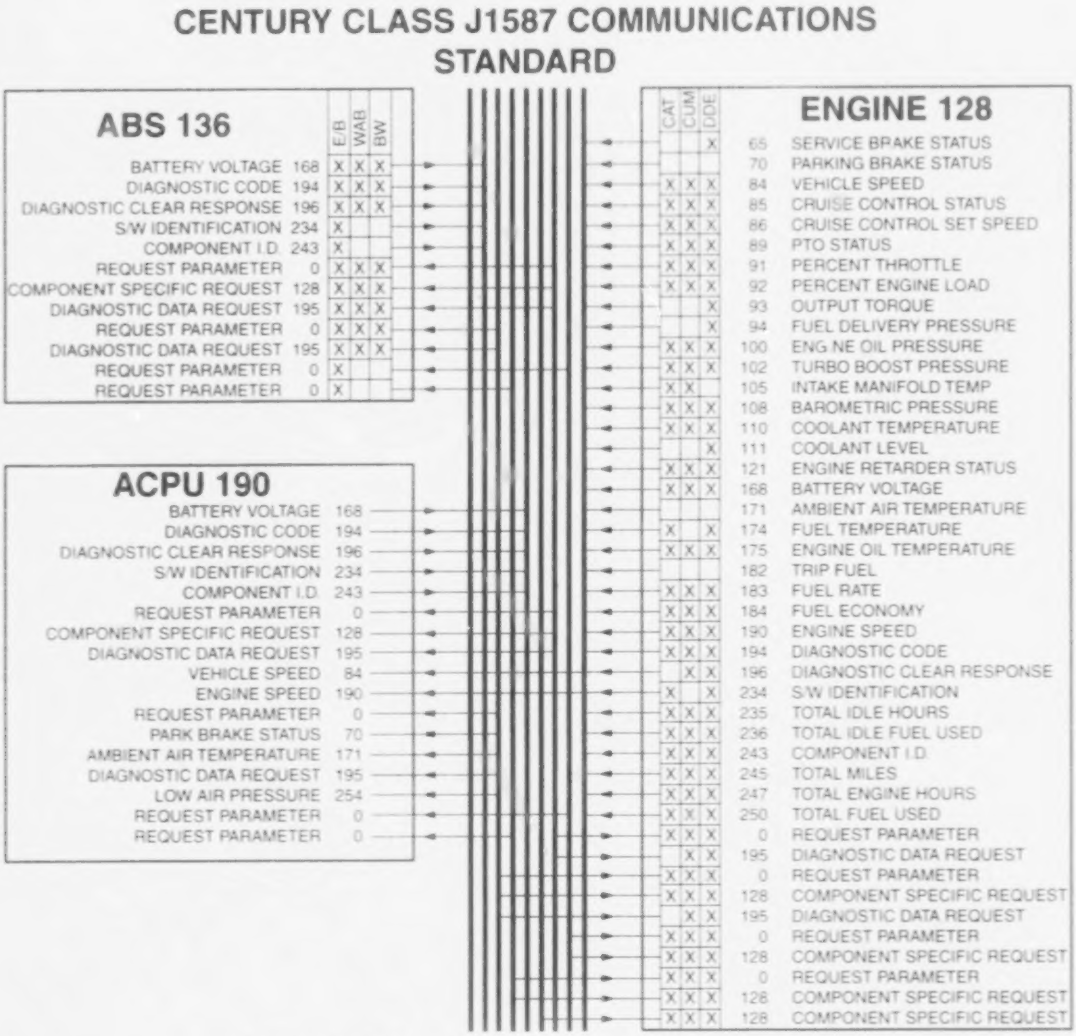
Objective 8

Flow of data through a simplified computer system

Figure 8—Example of Communications Map



CENTURY CLASS J1587 COMMUNICATIONS STANDARD

ABS 136

		E/B	WAB	BW
BATTERY VOLTAGE	168	X	X	X
DIAGNOSTIC CODE	194	X	X	X
DIAGNOSTIC CLEAR RESPONSE	196	X	X	X
S/W IDENTIFICATION	234	X		
COMPONENT I.D.	243	X		
REQUEST PARAMETER	0	X	X	X
COMPONENT SPECIFIC REQUEST	128	X	X	X
DIAGNOSTIC DATA REQUEST	195	X	X	X
REQUEST PARAMETER	0	X	X	X
DIAGNOSTIC DATA REQUEST	195	X	X	X
REQUEST PARAMETER	0	X		
REQUEST PARAMETER	0	X		

ACPU 190

BATTERY VOLTAGE	168
DIAGNOSTIC CODE	194
DIAGNOSTIC CLEAR RESPONSE	196
S/W IDENTIFICATION	234
COMPONENT I.D.	243
REQUEST PARAMETER	0
COMPONENT SPECIFIC REQUEST	128
DIAGNOSTIC DATA REQUEST	195
VEHICLE SPEED	84
ENGINE SPEED	190
REQUEST PARAMETER	0
PARK BRAKE STATUS	70
AMBIENT AIR TEMPERATURE	171
DIAGNOSTIC DATA REQUEST	195
LOW AIR PRESSURE	254
REQUEST PARAMETER	0
REQUEST PARAMETER	0

ENGINE 128

CAT	CUM	DDE		
		X	65	SERVICE BRAKE STATUS
			70	PARKING BRAKE STATUS
X	X	X	84	VEHICLE SPEED
X	X	X	85	CRUISE CONTROL STATUS
X	X	X	86	CRUISE CONTROL SET SPEED
X	X	X	89	PTO STATUS
X	X	X	91	PERCENT THROTTLE
X	X	X	92	PERCENT ENGINE LOAD
		X	93	OUTPUT TORQUE
		X	94	FUEL DELIVERY PRESSURE
X	X	X	100	ENGINE OIL PRESSURE
X	X	X	102	TURBO BOOST PRESSURE
X	X		105	INTAKE MANIFOLD TEMP
X	X	X	108	BAROMETRIC PRESSURE
X	X	X	110	COOLANT TEMPERATURE
		X	111	COOLANT LEVEL
X	X	X	121	ENGINE RETARDER STATUS
X	X	X	168	BATTERY VOLTAGE
			171	AMBIENT AIR TEMPERATURE
X		X	174	FUEL TEMPERATURE
X	X	X	175	ENGINE OIL TEMPERATURE
			182	TRIP FUEL
X	X	X	183	FUEL RATE
X	X	X	184	FUEL ECONOMY
X	X	X	190	ENGINE SPEED
X	X	X	194	DIAGNOSTIC CODE
	X	X	196	DIAGNOSTIC CLEAR RESPONSE
X		X	234	S/W IDENTIFICATION
X	X	X	235	TOTAL IDLE HOURS
X	X	X	236	TOTAL IDLE FUEL USED
X	X	X	243	COMPONENT I.D.
X	X	X	245	TOTAL MILES
X	X	X	247	TOTAL ENGINE HOURS
X	X	X	250	TOTAL FUEL USED
X	X	X	0	REQUEST PARAMETER
	X	X	195	DIAGNOSTIC DATA REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
	X	X	195	DIAGNOSTIC DATA REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
X	X	X	0	REQUEST PARAMETER
X	X	X	128	COMPONENT SPECIFIC REQUEST
X	X	X	128	COMPONENT SPECIFIC REQUEST

Courtesy of Freightliner LLC

1. Input voltage signals are sent to the computer from many sources. Sources include sensors, switches, other computers, and driver-operated controls. Data links carry this information.

2. An analog-to-digital interface receives the input signals and translates them into digital binary code as needed. (Some signals—such as from other computers, from switches, and from driver display panels—are already in digital binary code. Other signals—such as from temperature sensors—are usually analog signals.)

3. Time pulses from internal clocks help to separate one "message" from another.

4. The computer stores the input signals in memory. It tests the input signals against known or program values. This testing process may include making calculations and comparisons. (If a certain input drops out of a range deemed acceptable by the program, the program commands the computer to store a trouble/fault code for the specific fault.)

5. The computer retrieves stored input signals when a decision (correction or adjustment) must be made. For example:

   - The computer makes simple decisions. It watches the washer fluid level switch. When the switch reads "0 volt," the computer grounds the "low washer fluid" lamp.

   - The computer makes complex decisions. When it receives a signal requesting operation of the A/C compressor, the computer must process other data before responding. It must check other sensor inputs, such as engine and compressor conditions and the outside air temperature. If the signal values are acceptable, the computer sends the "engage A/C compressor" output signal.

6. The computer sends one or more output signals to other computers, to the driver information system, and/or to specific actuators to carry out the decision (solenoids, relays, or motors). A digital-to-analog interface converts the digital output signal into an analog signal, if needed.

Objective 9

Ways to retrieve diagnostic information from vehicle computers

Note: Fault/trouble codes can vary with the vehicle make, model, year, and engine type. Always check the appropriate service manual and other service publications.

a. Connecting a scan tool/diagnostic computer to a diagnostic/data link computer (DLC)

Figure 9—Scan tool

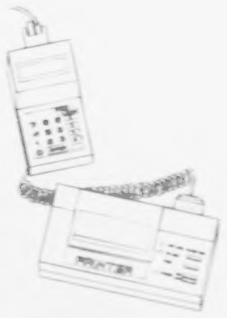
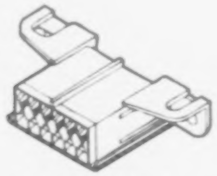


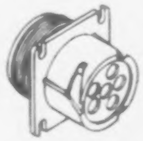
Figure 10—Laptop computer

Note: The DLC allows the technician to read input and output status, change calibrations, and retrieve diagnostic fault/trouble codes using a scan tool or laptop computer, or by reading flashing codes with a warning indicator lamp. Several companies manufacture cartridges and programs for scan tools/diagnostic computers to communicate with vehicle microprocessors.

Figure 11—Data Link Connectors



Rectangular Packard Connector



Round Deutsch Connector

Note: The DLC on most vehicles is located under the dash panel on the driver's side. On special purpose vehicles such as buses, coaches, and motor homes, the connector may be placed in a variety of locations.

b. Interpreting the pulses on a voltmeter

Example: It may be possible to retrieve the fault/trouble codes using an analog voltmeter and a jumper lead. Voltmeter pulses (needle movement from left to right) and pauses correspond to numbered trouble codes (as listed in the service manual). For example, two pulses, followed by a pause, followed by three pulses might represent trouble code #23.

Warning: Refer to the appropriate service manual to locate the correct terminals to jump. Damage to the computer may occur if the wrong terminals are jumped.

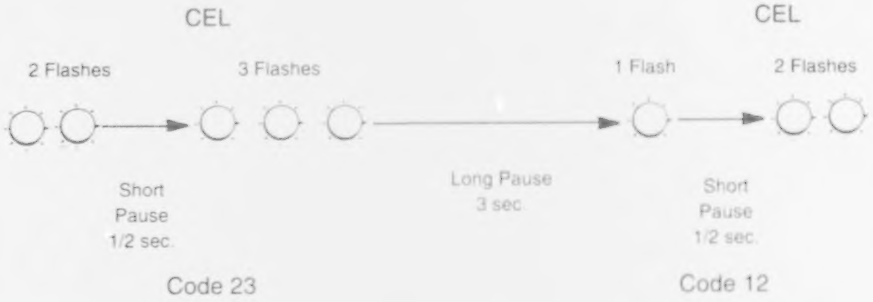
c. Interpreting the flashes on a test light.

Example: It may be possible to retrieve the fault/trouble codes using a 12-volt test light and a jumper wire. Light flashes from the test light correspond to numbered trouble codes (as listed in the service manual).

Warning: Refer to the appropriate service manual to locate the correct terminals to jump. Damage to the computer may occur if the wrong terminals are jumped.

d. Interpreting the flashes of a Check Engine Light (CEL)

Figure 12



Example: Some vehicle manufacturers mount a "Diagnostic Request" switch on the dash or next to the DLC. When pushed, the "Check Engine Light" will flash a number of times followed by a short pause and another set of flashes. The two sets of flashes represent a fault/trouble code. If there is another fault code to display, there will be a long pause before the flashing begins again. If the first code is repeated, then there are no more codes to display. Some systems will flash the active codes first using the "Stop Engine Light" (SEL), and the historical (non active) codes using the "Check Engine Light" (CEL).

Objective 10

SAE fault code identifiers

Note: Each fault code uses three number groups to describe the problem.

Example: 128 s175 03

a. First number group

- Message Identifier (MID)
- Identifies which microprocessor is broadcasting the code

b. Second number group—(PID or SID)

- Letter S or P preceding the number identifies the code as either a PID or SID
- Parameter Identifier (PID)—used to code components within an electronic subsystem
- Subsystem Identifier (SID)—identifies the major subsystems of an electronic circuit

c. Third number group

- Fault Mode Identifier (FMI)
- Identifies what is wrong with the sensor signal
- Indicates whether the problem relates to current flow or voltage

Student Supplement 1—Vehicle Computer Control Systems

Computer control systems usually consist of a microprocessor, sensors (input), and actuators (output) that interact with each other. The microprocessors collect data from sensors and react through the actuators to control many of today's vehicle operations. The input data can be stored for later retrieval and/or sent to other microprocessors on or off the vehicle. Most of the earlier microprocessors were only used for collecting trip data. Later, they were put on engines to meet government emissions regulations. Today's vehicles may have several microprocessors that make them easier and more efficient to operate. These include: climate control, cruise control, antilock braking, electronic transmissions, and more. Most microprocessors have a self-diagnostic function that stores fault codes and other information that can be retrieved at a later date by a qualified technician.

Computer control systems have been perfected throughout the years to provide reliability, efficiency, and responsiveness of today's vehicles. They've also been equipped with an adaptive strategy ability that compensates for mechanical wear and failure in order to keep the vehicle drivable.

Although there are several different vehicle, engine, and transmission manufacturers using different microprocessors, sensors, and actuators, they all operate in much the same manner. A malfunction from any device will log critical information in the memory of the microprocessor, which will be invaluable to the service technician in diagnosing and repairing the problem.

Many computer replacement parts require special handling. Some are very delicate and can be damaged easily. One disadvantage of a computer-controlled system is the need for a continued power source. Should vehicle voltage drop below 11 volts, the system may stop operating, lose programming, and/or cause the vehicle to stop operating.

Although computer control systems can be intimidating, an understanding of how the computer works and the interactions of its circuits and devices can reduce its complexity to simple tests and checks when servicing.

Student Supplement 2—How Information Travels Among Sensors, Computers, and Actuators

Overview

English has 26 letters that combine to form words. Numbering systems are built upon the numbers 0 to 9. With binary code, only two choices are used to build the language that the microprocessor can interpret. These two choices are called binary digits or bits. The two choices can be expressed as 0 and 1, on and off, or high and low. Input signals combine these bits to make words or bytes.

Computers represent four basic functions: input, processing, storage, and output. The input device sends a voltage signal to the microprocessor. The microprocessor uses the input information, calculates, and measures it with programmed instructions. The logic circuits of the computer check the input information with its programmed instructions. After a decision has been made by the computer, various output devices are sent output signals to specific loads, a system actuator, and/or another computer that correct or maintain the system being monitored.

Some programmed instructions are stored in an electronic memory for immediate use while other instructions are stored for later processing. Some output commands warn the driver of a condition of the system being monitored, such as the seat belt warning system.

Input

Input devices are sensors that gather information and send voltage signals to the microprocessor. Different types of protection and control devices can act as input sensors to detect operation information. As the resistance in the sensor changes, the voltage signal returning to the computer changes in proportion to the change in the condition of the system being monitored. When an input signal from a sensor changes, the microprocessor determines if an output is needed to compensate for the new condition.

If the sensor signal is weak, an amplifier may be used in the computer to strengthen it. A buffer may also be used to temporarily store information or to protect the computer from improper information. For example, if the sensor is sending the information too quickly for the microprocessor to process, the buffer will hold the information and send it as instructed.

Programs that read voltage signals are burned into integrated circuit chips using a series of numbers. Microprocessors use digital voltage readings. If the signal is analog, it must be changed into a digital signal. This is done through an analog-to-digital (A/D) converter. Some automakers house the A/D converter in the microprocessing unit. The converter assigns a numeric value to a specific voltage reading, then converts and translates the digital reading into a binary code.

Sensors can be either passive or active. Active sensors, such as the antilock brake sensor or the variable speed sensor, generate their own voltage signal. Passive sensors rely on external sources of voltage (reference voltage) to signal the microprocessor. With a passive sensor, a consistent voltage is needed to read the internal resistance of its transducer. For example, temperature sensors are fed reference voltage from the microprocessor. A change in sensor resistance can be read by the microprocessor as a change in current and voltage or a change in temperature.

Microprocessor

Microprocessors are computer chips or integrated circuits. They use binary code to analyze data and to calculate what should be done. Digital pulses are used by the logic gates in the processor to make decisions, comparisons, or calculations. (Logic gates are field-effect resistors incorporated into the computer.) It can take thousands of logic gates to make hundreds of different output decisions. The microprocessor uses stored data to compare input information in order to decide what the outputs should be for the best operating efficiency.

Microprocessors contain numerous registers or temporary memory cells. Mathematical operations are performed by shifting bytes back and forth through these registers. A computer can basically add, subtract, and accumulate data at a very high speed. Complex mathematical calculations are broken down into simple steps which the microprocessor can then calculate.

Memory

Integrated circuits capable of storing information as voltage charges are responsible for the memory of a computer. Theses memory chips hold their information until the microprocessor needs it. There are different methods for storing digital information. The more common methods are random access memory (RAM), read only memory (ROM), programmable read only memory (PROM), and keep alive memory (KAM)

Read-Only Memory (ROM)

- stores permanent data that cannot be removed from memory
- memory chip contains standard information about the make and model of vehicle
- used by microprocessor to check vehicle performance by comparing input data from sensors to stored information
- used by microprocessor to calculate corrections if needed to improve vehicle performance
- can be "read from" but not "written onto"
- soldered into the computer

Random Access Memory (RAM)

- stores information temporarily
- can be read by the microprocessor to make its calculations
- can be written on by the microprocessor for temporary storage
- can be used as a "notepad" to remember input and output data
- erases memory when battery voltage is disconnected
- soldered into the computer

Programmable Read-Only Memory (PROM)

- contains permanent data similar to ROM but more specific (shift points, gear ratios, number of cylinders, valve sizes, fuel system type, and unique concerns about that particular vehicle)
- only kind of memory that might need service
- modules can be removed and replaced
- microprocessor cannot write onto

Erasable Programmable Memory (EPROM)

- similar to a PROM except that its contents can be erasable to allow new data to be installed
- exposing the circuit to ultraviolet light will erase its contents

Electronically Erasable Programmable Memory (EEPROM)

- contains programmable options and propriety data that can be altered to meet the user's needs
- allows information to be changed one bit at a time
- some information can be changed with a scan tool; other information can be changed with a laptop computer and a disc provided by the OEM

Keep Alive Memory (KAM)

- allows computer to have adaptive strategy (maintains operation of vehicle when parts and components deteriorate or wear, giving abnormal input signals)
- can transform an abnormal signal to a normal signal
- stores data temporarily

- microprocessor can write onto it
- retains information when ignition key and engine are turned off
- KAM memory is lost when battery power is disconnected from the computer

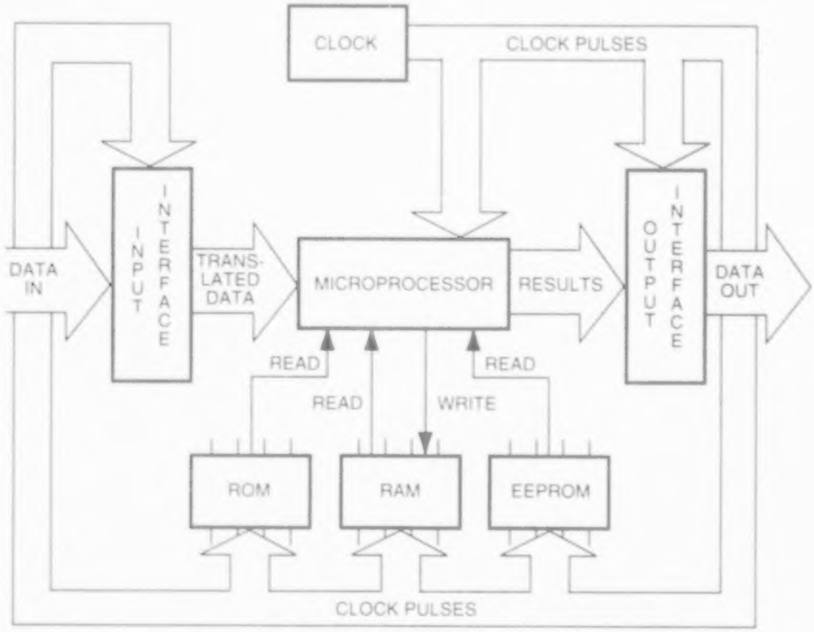
  Note: When a bad sensor, actuator, or other component is replaced, KAM may still try to correct the bad input for a few miles. This makes the vehicle perform worse than before. It will correct itself when it "learns" the new good component has been installed.

Output

After receiving input signals, the microprocessor can calculate and determine if changes are needed. After this calculation, the microprocessor may produce an output signal. Usually this signal is sent to an A/D converter that changes the digital output into an analog output. The analog voltage then powers a driver. The actuator makes the necessary adjustments for the engine to operate efficiently.

Vehicle computers have an internal clock. The constant time pulses from the clock help to maintain an orderly flow of information. Each pulse is the length of one bit of digital (binary) code. This allows the microprocessor to distinguish between binary codes such as 01 and 0011.

Figure 1


CLOCK
CLOCK PULSES
DATA IN
INPUT INTERFACE
TRANS-LATED DATA
MICROPROCESSOR
RESULTS
OUTPUT INTERFACE
DATA OUT
READ
READ
WRITE
READ
ROM
RAM
EEPROM
CLOCK PULSES

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In addition to the computer on the vehicle, computers are also used in diagnosing engine problems. When a certain input or output drops out of a range deemed acceptable by the controller's program, the program commands the controller to store a fault code for the specific fault. These fault codes are the communication link between various modules in the vehicle and the technician. The technician can run system diagnostics through the data link connector (DLC). The connector allows the technician to read diagnostic fault codes using a scan tool, a laptop computer, or by reading flashing codes with a warning indicator lamp.

Scan tools and diagnostic computers assist the technician by displaying codes which correspond to specific malfunctions reported by the vehicle computer. The service manual for the vehicle will explain the codes or flashing lights.

Student Supplement 3—Information Monitored by Sensors

SENSOR	INFORMATION MONITORED
air temperature sensor	measures ambient air and the air temperature entering the engine intake manifold and cab
turbo boost (MAP) sensor	measures amount of air flowing into engine
barometric pressure sensor	measures atmospheric pressure around the engine
brake sensor	measures brake pedal application
crank position sensor	measures rotation or location of crankshaft
engine speed sensor	measures engine rpm
engine temperature sensor	measures temperature of engine coolant
oil level sensor	measures amount of oil in engine oil pan
throttle position sensor	measures angle of the throttle pedal
vehicle speed sensor	measures transmission output speed
oil/fuel pressure sensor	measures oil/fuel pressure
fuel temperature sensor	measures temperature of fuel
coolant level sensor	measures amount of engine coolant circulating through the engine

Student Supplement 4—Functions Controlled by Actuators

ACTUATOR	FUNCTION CONTROLLED
injector solenoids	regulates the amount of fuel entering the engine
ABS hydraulic solenoid	regulates the amount of fluid pressure applied to the brake assembly(s) during hard braking
cooling fan solenoid	cools the engine coolant
transmission shift solenoid	opens or closes a hydraulic valve that applies clutches
engine brake solenoid	opens a hydraulic valve that holds exhaust valves to make the engine perform as a brake
exhaust brake solenoid	opens a pneumatic valve that uses a cylinder to close a flapper in the exhaust system
retarder solenoid	opens a pneumatic valve that applies an accumulator to apply the retarder

Student Supplement 5—SAE Codes

Table 1—Message Identifiers (MIDs)

MID	Description
128	Engine Controller
130	Transmission
136	Brakes—Antilock/Traction Control
137-139	Brakes—Antilock, Trailer #1, #2, #3
140	Instrument Cluster
141	Trip Recorder
142	Vehicle Management System
143	Fuel System
162	Vehicle Navigation
163	Vehicle Security
165	Communication Unit—Ground
171	Driver Information System
178	Vehicle Sensors to Data Converter
181	Communication Unit—Satellite

Table 2—Parameter Identifiers (PIDs)	
PID	**Description**
51	Throttle Position
52	Engine Intercooler Temperature
53	Transmission Synchronizer Clutch Value
54	Transmission Synchronizer Brake Value
55	Shift Finger Positional Status
56	Transmission Range Switch Status
57	Transmission Actuator Status #2
58	Shift Finger Actuator Status
59	Shift Finger Gear Position
60	Shift Finger Rail Position
61	Parking Brake Actuator Status
62	Retarder Inhibit Status
63	Transmission Actuator Status #1
64	Direction Switch Status
65	Service Brake Switch Status
66	Vehicle Enabling Component Status
67	Shift Request Switch Status
68	Torque Limiting Factor
69	Two-Speed Axle Switch Status
70	Parking Brake Switch
71	Idle Shutdown Timer Status
72	Blower Bypass Value Position
73	Auxiliary Water Pump Pressure
74	Maximum Road Speed Limit
75	Steering Axle Temperature
76	Axle Lift Air Pressure
77	Forward Rear Drive Axle Temperature
78	Rear Rear Drive Axle Temperature
79	Road Surface Temperature

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Table 2—Parameter Identifiers (PIDs)

PID	Description
80	Washer Fluid Level
81	Particulate Trap Inlet Pressure
82	Air Start Pressure
83	Road Speed Limit Status
84	Road Speed
85	Cruise Control Status
86	Cruise Control Set Speed
87	Cruise Control High—Set Limit Speed
88	Cruise Control Low—Set Limit Speed
89	Power Takeoff Status
90	PTO Oil Temperature
91	Percent Accelerator Pedal Position
92	Percent Engine Load
93	Output Torque
94	Fuel Delivery Pressure
95	Fuel Filter Differential Pressure
96	Fuel Level
97	Water in Fuel Indicator
98	Engine Oil Level
99	Engine Oil Filter Differential Pressure
100	Engine Oil Pressure
101	Crankcase Pressure
102	Boost Pressure
103	Turbo Speed
104	Turbo Oil Pressure
105	Intake Manifold Temperature
106	Air Inlet Pressure
107	Air Filter Differential Pressure
108	Barometric Pressure
109	Coolant Pressure

110	Engine Coolant Temperature
111	Coolant Level
112	Coolant Filter Differential Pressure
113	Governor Droop
114	Net Battery Current
115	Alternator Current
116	Brake Application Pressure
117	Brake Primary Pressure
118	Brake Secondary Pressure
119	Hydraulic Retarder Pressure
120	Hydraulic Retarder Oil Temperature
121	Engine Retarder Status
122	Engine Retarder Percent
123	Clutch Pressure
124	Transmission Oil Level
125	Transmission Oil Level High/Low
126	Transmission Filter Differential Pressure
127	Transmission Oil Pressure
154	Auxiliary Input and Output Status #2
155	Auxiliary Input and Output Status #1
156	Injector Timing Rail Pressure
157	Injector Metering Rail Pressure
158	Battery Potential (voltage)—Switched
159	Gas Supply Pressure
160	Main Shaft Speed
161	Input Shaft Speed
162	Transmission Range Selected
163	Transmission Range Attained
164	Injection Control Pressure
165	Compass Bearing
166	Rated Engine Power
167	Alternator Potential (voltage)

168	Battery Potential (voltage)
169	Cargo Ambient Temperature
170	Cab Interior Temperature
171	Ambient Air Temperature
172	Air Inlet Temperature
173	Exhaust Gas Temperature
174	Fuel Temperature
175	Engine Oil Temperature
176	Turbo Oil Temperature
177	Transmission Oil Temperature
178	Front Axle Weight
179	Rear Axle Weight
180	Trailer Weight
181	Cargo Weight
182	Trip Fuel
183	Fuel Rate
184	Instantaneous Fuel Economy
185	Average Fuel Economy
186	Power Takeoff Speed
187	Power Takeoff Set Speed
188	Idle Engine Speed
189	Rated Engine Speed
190	Engine Speed
191	Transmission Output Shaft Speed
232	DGPS Differential Correction
233	Power Unit Number
234	Software Identification
235	Total Idle Hours
236	Total Idle Fuel Used
237	Vehicle Identification Number
238	Velocity Vector
239	Vehicle Position

240	Change Reference Number
241	Tire Pressure
242	Tire Temperature
243	Component Identification
244	Trip Distance
245	Total Vehicle Distance
246	Total Vehicle Hours
247	Total Engine Hours
248	Total PTO Hours
249	Total Engine Revolutions
250	Total Fuel Used
251	Clock
252	Date
253	Elapsed Time

Table 3—MID 128 Engine Sub-System Identifiers (SIDs)

SID	Description
1	Injector Cylinder #1
2	Injector Cylinder #2
3	Injector Cylinder #3
4	Injector Cylinder #4
5	Injector Cylinder #5
6	Injector Cylinder #6
7	Injector Cylinder #7
8	Injector Cylinder #8
9	Injector Cylinder #9
10	Injector Cylinder #10
11	Injector Cylinder #11
12	Injector Cylinder #12
13	Injector Cylinder #13
14	Injector Cylinder #14

15	Injector Cylinder #15
16	Injector Cylinder #16
17	Fuel Shutoff Valve
18	Fuel Control Valve
19	Throttle Bypass Valve
20	Timing Actuator
21	Engine Position Sensor
22	Timing Sensor
23	Rack Actuator
24	Rack Position Sensor
25	External Engine Protection Input
26	Auxiliary Output Device Driver #1
27	Variable Geometry Turbocharger Actuator #1
28	Variable Geometry Turbocharger Actuator #2
29	External Fuel Command Input
30	External Speed Command Input
31	Tachometer Signal Output
32	Wastegate Output Device Driver
33	Fan Clutch Output Device Driver
34	Exhaust Back Pressure Sensor
35	Exhaust Back Pressure Regulator Solenoid
36	Glow Plug Lamp
37	Electronic Drive Unit Power Relay
38	Glow Plug Relay
39	Engine Starter Motor Relay
40	Auxiliary Output Device Driver #2
41	ECM 8 Volts DC Supply
42	Injection Control Pressure Regulator
43	Autoshift High Gear Actuator
44	Autoshift Low Gear Actuator
45	Autoshift Neutral Gear Actuator
46	Autoshift Common Low Side (Return)

47	Injector Cylinder #17
48	Injector Cylinder #18
49	Injector Cylinder #19
50	Injector Cylinder #20
51	Auxiliary Output Device Driver #3
52	Auxiliary Output Device Driver #4
53	Auxiliary Output Device Driver #5
54	Auxiliary Output Device Driver #6
55	Auxiliary Output Device Driver #7
56	Auxiliary Output Device Driver #8
57	Auxiliary PWN Driver #1
58	Auxiliary PWN Driver #2
59	Auxiliary PWN Driver #3
60	Auxiliary PWN Driver #4
61	Variable Swirl System Valve
62	Prestroke Sensor
63	Prestroke Actuator
64	Engine Speed Sensor #2
65	Heated Oxygen Sensor
66	Ignition Control Mode Signal
67	Ignition Control Timing Signal
68	Secondary Turbo Inlet Pressure
69	ACOC (Aftercooler/Oil Cooler) Coolant Temp
70	Inlet Air Heater Driver #1
71	Inlet Air Heater Driver #2
72	Injector Cylinder #21
73	Injector Cylinder #22
74	Injector Cylinder #23
75	Injector Cylinder #24
76	Knock Sensor
77	Gas Metering Valve

Table 4—MID 136 ABS Sub-System Identifiers (SIDs)	
SID	**Description**
1	Wheel Sensor ABS Axle 1 Left
2	Wheel Sensor ABS Axle 1 Right
3	Wheel Sensor ABS Axle 2 Left
4	Wheel Sensor ABS Axle 2 Right
5	Wheel Sensor ABS Axle 3 Left
6	Wheel Sensor ABS Axle 3 Right
7	Pressure Modulation Valve ABS Axle 1 Left
8	Pressure Modulation Valve ABS Axle 1 Right
9	Pressure Modulation Valve ABS Axle 2 Left
10	Pressure Modulation Valve ABS Axle 2 Right
11	Pressure Modulation Valve ABS Axle 3 Left
12	Pressure Modulation Valve ABS Axle 3 Right
13	Retarder Control Relay
14	Relay Diagonal 1
15	Relay Diagonal 2
16	Mode Switch ABS
17	Mode Switch ASR
18	DIF 4–ASR Valve
19	DIF 2–ASR Valve
20	Pneumatic Engine Control
21	Electronic Engine Control (Servomotor)
22	Speed Signal Input
23	Warming Light Bulb
24	ASR Light Bulb
25	Wheel Sensor, ABS Axle 1 Average
26	Wheel Sensor, ABS Axle 2 Average
27	Wheel Sensor, ABS Axle 3 Average
28	Pressure Modulator, Drive Axle Relay Valve
29	Pressure Transducer, Drive Axle Relay Valve
30	Master Control Relay

Student Supplement 5

Table 4—MIC 136 ABS Sub-System Identifiers (SIDs)

SID	Description
31	Trailer Brake Slack Out of Adjust Frwrd Axle Left
32	Trailer Brake Slack Out of Adjust Frwrd Axle Right
33	Trailer Brake Slack Out of Adjust Rear Axle Left
34	Trailer Brake Slack Out of Adjust Rear Axle Right
35	Tractor Brake Slack Out of Adjust Axle 1 Left
36	Tractor Brake Slack Out of Adjust Axle 1 Right
37	Tractor Brake Slack Out of Adjust Axle 2 Left
38	Tractor Brake Slack Out of Adjust Axle 2 Right
39	Tractor Brake Slack Out of Adjust Axle 3 Left
40	Tractor Brake Slack Out of Adjust Axle 3 Right

Table 5—MIC 190 APADS Sub-System Identifiers (SIDs)

SID	Description
1	Refrigerant Charge
2	Refrigerant Moisture Level
3	Non-Condensable Gas in Refrigerant
4	Refrigerant Flow Control Solenoid
5	Low Pressure Switch
6	Refrigerant Clutch Circuit
7	Evaporator Thermostat Circuit
228	High Pressure Switch

Table 6—Failure Mode Identifiers (FMIs)	
FMI	**Description and Comments**
00	Above normal operating range, for example: engine overheating (required diagnostic information)
01	Below normal operating range, for example: engine oil pressure too low (required diagnostic information)
02	Erratic, intermittent, or incorrect data
03	Voltage above normal or shorted high
04	Voltage below normal or shorted low
05	Current below normal or open circuit
06	Current above normal or circuit shorted to ground
07	Mechanical system not responding properly
08	Abnormal frequency, pulse width, or period
09	Abnormal update rate
10	Abnormal rate of change
11	Failure node not identifiable
12	Bad intelligent device or component
13	Out of calibration
14	Special instructions
15	Reserved for future assignment

All information for Student Supplement 5 courtesy of Freightliner LLC.

Objective 11

Assignment Sheet 1—Demonstrate How a Potentiometer Functions as a Sensor

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Circuit built correctly	______
• Equipment connected properly	______
• Answered all questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking

Introduction

Sensors are input devices. They convert physical conditions—such as position or temperature—into electrical signals (voltage). Many electronic devices also act as sensors. Input devices are sensors that gather information and send voltage signals to the microprocessor. Different types of protection and control devices can act as input sensors to detect operation information. As the resistance in the sensor changes, the voltage signal returning to the computer changes in proportion to the change in the condition of the system being monitored. When an input signal from a sensor changes, the microprocessor determines if an output is needed to compensate for the new condition.

Materials list

- 10K Potentiometer, 1/4 watt
- 4-2.5K Resistors, 1/4 watt

Directions

Build the circuit shown on the following page and answer the following questions by placing your answer in the blank provided.

1. Between which terminals of the potentiometer is the voltage drop being read?

   ____

2. Turn the knob of the potentiometer.

   a. What is the minimum voltage?

   ____

   b. What is the maximum voltage?

   ____

3. Replace the potentiometer with the four resistors in series. (Keep the black lead at ground.)

Voltage #1: ____________________

Voltage #2: ____________________

Voltage #3: ____________________

Voltage #4: ____________________

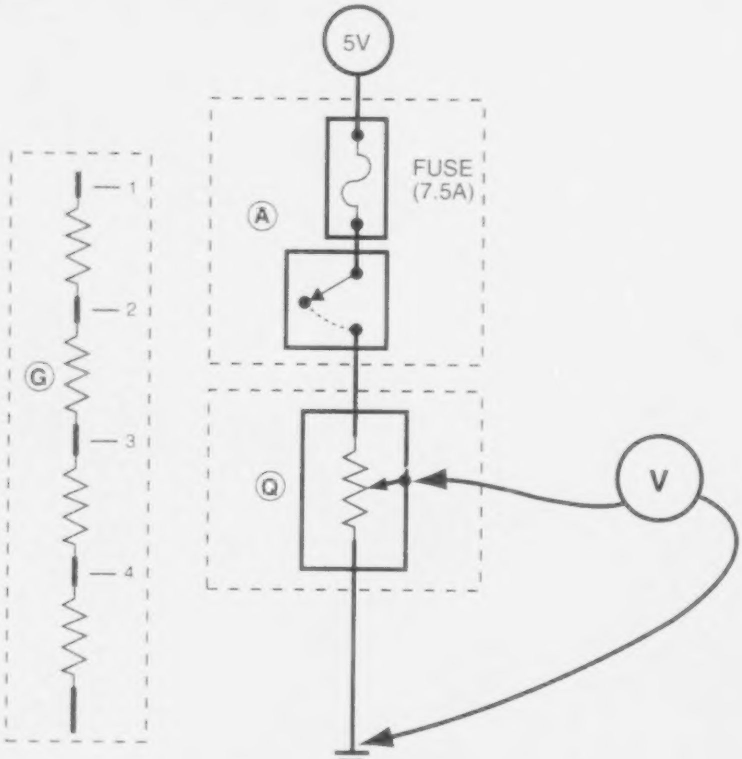
4. Connect the black terminal of the meter to the ground and measure voltage drop at points 1, 2, 3, and 4. Discuss the results with your instructor. What have you learned?

____

____

____

Figure 1



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Objective 12

Assignment Sheet 2—Interpret SAE Fault Code Identifiers

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered all questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading Mathematics Critical Thinking

Introduction

SAE fault codes help you quickly locate malfunctions by narrowing your search. Accurately interpreting what the system is telling you greatly reduces your troubleshooting effort.

Directions

Listed below are six trouble codes. Using Student Supplement 5, identify each of the three segments for each code. Next, using the information given by the three segments of the code identifier, describe the fault.

Example:	128 110 04		
a.	MID	128	Engine
b.	PID/SID	110	Engine Coolant Temperature
c.	FMI:	04	Voltage below normal or shorted low
c.	Fault description		Engine temp sensor bad

1. 128 s022 04

   a. MID ______________________________

   b. PID/SID ______________________________

   c. FMI ______________________________

   d. Fault Description ______________________________

868

2. 171 p080 13

   a. MID ________________________________

   b. PID/SID ________________________________

   c. FMI ________________________________

   d. Fault Description ________________________________

3. 143 p096 02

   a. MID ________________________________

   b. PID/SID ________________________________

   c. FMI ________________________________

   d. Fault Description ________________________________

4. 171 p108 06

   a. MID ________________________________

   b. PID/SID ________________________________

   c. FMI ________________________________

   d. Fault Description ________________________________

5. 128 p167 00

   a. MID ________________________________

   b. PID/SID ________________________________

   c. FMI ________________________________

   d. Fault Description ________________________________

6. 128 p100 01

   a. MID ________________________________

   b. PID/SID ________________________________

   c. FMI ________________________________

   d. Fault Description ________________________________

Objective 13

Job Sheet 1—Use a DVOM to Measure Reference Voltage Output From the Electronic Control Module

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability Critical Thinking

Introduction

The control module reference voltage can be for a sensor, current flow to an actuator, or a voltage signal to an actuator/solenoid. Most computers use a reference voltage of about 5 volts. However, some systems have a different reference voltage.

- Read the DVOM owner's manual before using the DVOM.

- Before using a DVOM, run a performance check. The performance check tells you whether the DVOM is working correctly. It also checks the fuses that protect the device.

- Always check the appropriate service manual for correct reference voltage.

- If the DVOM measures inappropriate reference voltage, it does not necessarily mean the computer unit is bad. Look for broken, loose, or frayed wiring as a possible cause.

- Always refer to the appropriate service manual for the proper way to connect the DVOM to the ECM. When dealing with the vehicle's electrical system, it is always possible to damage electronic parts with improper connections.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 1

Tools, equipment, and materials

- DVOM
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 14

Job Sheet 2—Access Vehicle Fault Codes Using the Vehicle's Computerized Diagnostic System; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Scan tool/laptop computer connected properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

Accessing fault codes

Most vehicles with computer-controlled systems have a self-diagnosis feature that produces and stores fault codes when an operating parameter is exceeded. The ECM can interact with a variety of sensors, actuators, and other computers, while it scans input and output circuits to detect incorrect voltage, resistance, or current readings. The computer produces a fault code that can be compared to a fault code chart in the service manual. By comparing the fault code to the chart, you can determine the area or circuit with the abnormal condition, giving you a place and a systematic process to begin testing.

The method of retrieving vehicle fault codes varies with each manufacturer. The most common method is when the dash warning ("Check Engine") light comes on or flashes a warning to the driver that the computer has detected an operating fault and that service is required. When it is safe to get off the road, the driver can pull over and push the diagnostic request button, if so equipped. The light will flash out a series of codes letting him/her make a decision to either keep driving to the next service center or call for service. If the vehicle is not equipped with a diagnostic request button, the driver should proceed to the closest service center that's equipped with diagnostic equipment.

Common problems

Common computer system problems include:

- Computer malfunction

- Corroded or loose electrical connections
- Engine, fuel, or charging system problems
- Failed actuators
- Failed sensors
- Open or shorted circuits

Once the codes are retrieved, check them against the chart in the service manual.

Erasing fault codes

Erasing fault codes usually involves one of the following:

Note: These are examples of how to erase fault codes, but do not represent every way to erase fault codes. Consult the vehicle or equipment manufacturer to determine the method of erasing their fault codes.

- Cycling the ignition 3 to 6 times (depending on the manufacturer). If the code does not return, it was erased from the ECM
- Disconnecting the battery from the ECM (depending on the manufacturer)
- Unplugging the ECM harness (depending on the manufacturer and the generation of the ECM)
- Using a scan tool/laptop computer to erase fault codes from the ECM

  Note: To erase some fault codes, an OEM password may be required.

After reconnecting the ECM, always check the system to make sure it is working properly.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Scan tool or laptop computer with appropriate software
- Data link connector
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________

Address ____________

Phone # ____________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________

Customer Address ____________

Customer Phone # ____________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________

Services/repairs made: ____________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________ Date ____________

Technician ____________

Supervisor ____________

Unit 5

Battery Diagnosis and Servicing

Unit Contents

Student Components

Student Page

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Information Sheet 5-5

Student Supplement

1—How a Battery Works 5-15

Assignment Sheet

1—Evaluate Factors in Selecting the Appropriate Battery for a Vehicle 5-19

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6—Slow and Fast Charge a Battery 5-61
7—Diagnose Parasitic (key-off) Battery Drain Problems 5-73
8—Connect Batteries in Series, Parallel, and Series-Parallel 5-77
9—Jump-Start a Vehicle 5-81

Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose battery problems using common test equipment and procedures, and service a battery and its related equipment. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to battery diagnosis and repair to their correct definitions.
2. Label battery service tools used by diesel technicians.
3. List five functions of the battery.
4. Match types of batteries to their descriptions.
5. Match ratings of batteries to their descriptions.
6. List four factors affecting correct battery selection.
7. List safety rules for working with batteries.
8. Match types of battery connections to their correct system.
9. Evaluate factors in selecting the appropriate battery for a vehicle. (Assignment Sheet 1)
10. Maintain and restore electronic memory functions. (Job Sheet 1)
11. Inspect, clean, fill, and replace a battery, battery cables, connectors, clamps, battery box, and hold-downs. (Job Sheet 2)
12. Make a battery state-of-charge test. (Job Sheet 3)
13. Make a battery capacity (load) test. (Job Sheet 4)
14. Determine battery state-of-charge using an open circuit voltage test. (Job Sheet 5)
15. Slow and fast charge a battery. (Job Sheet 6)
16. Diagnose parasitic (key-off) battery drain problems. (Job Sheet 7)
17. Connect batteries in series, parallel, and series-parallel. (Job Sheet 8)
18. Jump-start a vehicle. (Job Sheet 9)

Information Sheet

Objective 1

Terms and definitions

a. **Aftermarket**—A product installed on a vehicle after it is manufactured

b. **Battery**—Two or more connected cells that convert chemical energy into electrical energy

c. **Cell**—One positive plate group and one negative plate group

d. **Cold cranking amps** (CCA)—Determines how much current a 12-volt battery can supply for a 30 seconds at 0° F without dropping below 8.5 volts

e. **Electrolyte**—Solution of water and sulfuric acid

f. **Hydrometer**—A test instrument for determining the specific gravity of electrolyte

g. **Reserve capacity rating** (RC)—Indicates how many minutes a fully charged battery operating at 80° F can supply a current of 25 amps, before the battery voltage drops below 10.5 volts

h. **Short**—An unwanted electrical path that sometimes goes directly to the ground

i. **Specific gravity**—Weight of electrolyte compared to an equal volume of water at 60° F

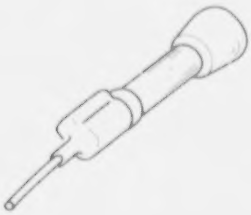
j. **Sulfated**—Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

Objective 2

Battery service tools

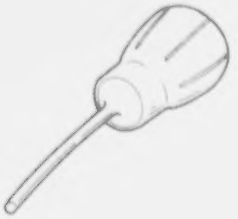
a. **Battery hydrometer**—Used to measure electrolyte's specific gravity (state of charge)

Figure 1



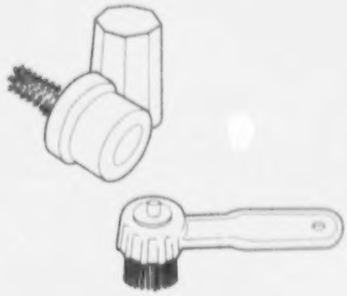
b. **Battery syringe**—Used to fill battery cells

Figure 2



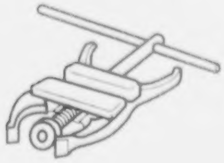
c. **Battery post cleaner**

Figure 3



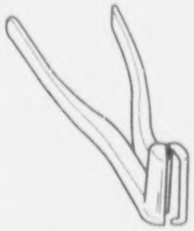
d. **Battery terminal clamp puller**

Figure 4



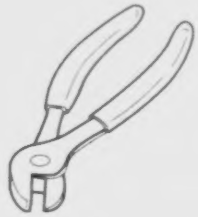
e. **Terminal spreader plier**

Figure 5



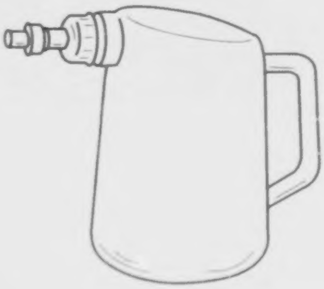
f. **Angle nose (battery bolt) plier**

Figure 6



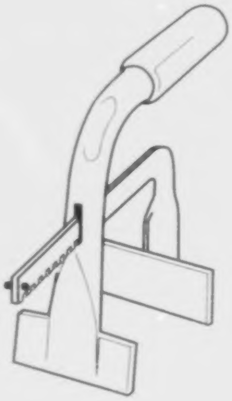
g. **Automatic battery filler**

Figure 7



h. **Battery carrier**

Figure 8



Objective 3

Five functions of the battery

a. Stores electricity

b. Provides electricity to start the engine

Note: This includes the operation of the starting motor, ignition system, electronic fuel injection, and other electrical devices.

c. Stabilize voltage for the vehicle's electrical system

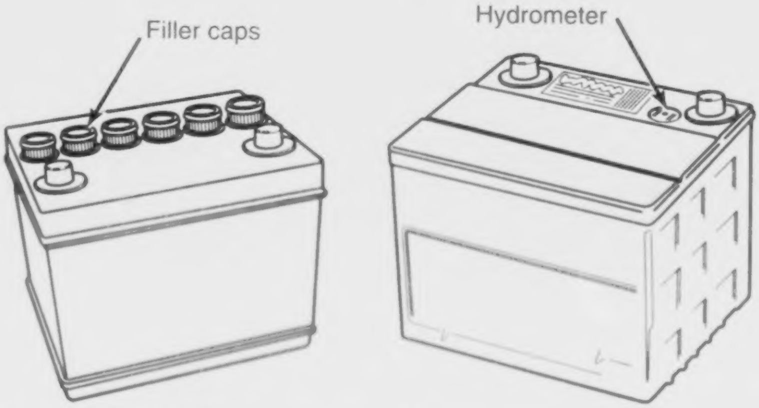
d. Provides electricity whenever the vehicle's electrical demands are greater than the charging system output

e. Provides electricity for vehicle accessories when the engine is not running or the charging system is not working

Objective 4

Types of vehicle batteries and their descriptions

Figure 9



Conventional battery **Low-maintenance battery**

a. **Conventional battery**—Distilled water must be occasionally added to the battery through removable filler caps to keep the battery operating correctly.

Note: When a battery is being charged, it gives off a gas containing chemicals and water. In a conventional battery, the water carried off in this gas must be periodically replaced by adding additional water to the battery. Vent holes located in the cell caps of conventional batteries vent the gas to the outside air. Distilled water must be used because the elements present in ordinary tap water will damage the battery.

b. **Low-maintenance battery**—The most common type of battery, their special construction greatly reduces the need to add distilled water to keep the battery operating.

Note: A low-maintenance battery uses calcium to reduce the production of battery gases, greatly reducing the need to add distilled water. Low-maintenance batteries usually have a solid plate (of one or two pieces) covering the filler caps on top of the battery. Although you should occasionally check the electrolyte level in a low-maintenance battery, you will seldom need to add additional water. In fact, some low-maintenance batteries have no filler caps, and you never add water to the battery. On such a battery, a battery charge indicator (called a *hydrometer*) located on the top of the battery changes color to indicate whether or not the battery needs to be charged.

c. **Gel cell battery**—A lead-acid battery having a pressurized case that should never be opened.

Note: Gel cell batteries contain a substance called thixotropic gelled electrolyte that liquefies when shaken. The substance returns to a solid state once it is allowed to rest. Because of its design, there is no loss of liquid like that normally found in a conventional battery. A gel cell battery should not be charged with a standard batter charger. Most battery chargers operate at a rate of 16 volts and this will damage a gel cell battery. Gel cell battery chargers operate at a rate of 13.8 to 14.2 volts. Never charge a gel cell battery at more than 14.2 volts.

Objective 5

Ratings of batteries and their descriptions

Note: Battery capacity ratings are standardized by the Battery Council International (BCI) and the Society of Automotive Engineers (SAE). Battery voltage depends on the materials used in constructing the battery. Current capacity depends on the size of the cell plates in the battery, the amount of chemically active materials used in the plates, and the strength of the sulfuric acid in the electrolyte solution in the battery. Examine a battery catalog to become more familiar with automotive battery ratings.

a. **Cold cranking amps (CCA) rating**—indicates how much current (in amps) a 12-volt battery can supply for 30 seconds at 0° F without dropping below 8.5 volts

Note: Cold cranking amps give you an idea of the battery's ability to deliver current to start the vehicle at low temperatures. This is the most common method of rating batteries. Cold cranking ratings for 12-volt batteries commonly range from 405 CCA to 900 CCA.

b. **Reserve capacity rating**—indicates how many minutes a fully-charged battery operating at 80° F can supply a current of 25 amps before the battery voltage drops below 10.5 volts

Note: The reserve capacity of a battery will give you an idea of how long a vehicle can be driven with the headlights on if the charging system should fail. Reserve capacity ratings for 12-volt batteries commonly range from 70-165 minutes.

Information Sheet

Objective 6

Factors affecting correct battery selection

a. **Manufacturer's recommended battery size**

Note: Battery size refers to the recommended rating of the battery—the recommended voltage, cold cranking rating, and other recommended ratings (see objective 5). Always refer to the vehicle's owner's manual or service manual for the manufacturer's specifications regarding battery size. If you know the size of the old battery, select a new battery that is the same size or preferably with 20% more CCA than the old battery or, if you know the vehicle's VIN number, you can take it to a parts supply store and they will be able to tell you the recommended battery size for the vehicle.

b. **The physical features of the battery**

Note: When choosing a battery, you should get a replacement battery that fits the battery holding fixture and hold-downs. The new battery should also have the same type of battery terminals in the same location on the battery. Terminals can be located either on the top or the side of the battery, depending on how the battery fits into the vehicle. The BCI publishes a standardized set of group numbers for batteries that indicate the physical size and other features of batteries. It is important that the battery have the proper physical dimensions so that it does not short to the hood or other nearby parts when it is installed and the hood is closed.

c. **Temperature of the climate in which the vehicle will operate**

Note: As the temperature drops, chemical action inside the battery slows down and battery power is reduced. Also, oil lubricating the engine is thicker at lower temperatures and the amount of current needed to crank the engine is increased. If the vehicle for which the battery is intended must operate at low temperatures, a more powerful than normal battery should be installed.

d. **Electrical options added to the vehicle after purchase**

Note: Optional aftermarket electrical equipment added to the vehicle place a greater demand on the battery. Air conditioning places a particularly large load on the battery. Remember that the manufacturer's recommended battery size, although it usually includes standard manufacturer-installed electrical options, does not ordinarily take into account aftermarket products the owner may install after the vehicle is purchased. If aftermarket electrical products have been installed, you need to select a battery larger than the manufacturer recommends in the owner's or service manual.

Objective 7

Safety rules for working with batteries

a. **Wear safety glass/face shield, rubber gloves, and a rubber apron when working with batteries.**

> **Warning:** The fluid inside batteries is a combination of sulfuric acid and water called an electrolyte. This electrolyte is highly corrosive. It will badly burn your eyes and skin and destroy your clothing. Protect yourself by covering your skin and clothing.

b. **Keep a mixture of baking soda and water nearby when working with batteries.**

Note: If electrolyte is accidentally spilled or splashed on clothing or skin, immediately wash the area with a baking soda and water solution (2 tablespoons of baking soda per quart of water) and then rinse with clean water. Keeping the mixture ready for use shortens the exposure time of the clothing or skin to the chemicals and may reduce the damage it causes.

c. **Use covers to protect the vehicle from accidental electrolyte spills.**

Note: If the electrolyte gets on any part of the vehicle, immediately wash the area with a mixture of baking soda and water and rinse with clean water.

d. **Do not smoke or have an open flame near a battery that is being charged or near a battery that has been recently charged.**

> **Warning:** Electrolyte gives off flammable gases, particularly when the battery is being charged and for the first few hours after it has been charged. Some of these gases escape through the battery's vent holes. Flames or sparks can ignite this gas and cause the battery to explode.

e. **Do not break live circuits at the battery.**

> **Warning:** The vehicle and any accessories should be turned off before either cable to the battery is disconnected. If any circuit is live when the battery is disconnected, sparks will occur around the battery that may ignite battery gases, causing the battery to explode. Breaking live circuits at the battery may also cause voltage spikes that will damage circuit devices.

f. **When disconnecting the battery, disconnect the negative cable first.**

g. **When reconnecting the battery, reconnect the positive cable first.**

> **Warning:** Disconnecting and reconnecting battery cables incorrectly is a common cause of electrical arcs that may ignite battery gases, causing the battery to explode.

h. **Remove metal rings and jewelry before working on the battery.**

Warning: Most metal jewelry is an excellent conductor of electricity. If metal jewelry accidentally contacts a battery terminal, severe burns may result.

i. **Unplug/turn off the battery charger before connecting or disconnecting it to the battery.**

Warning: A spark may result when connecting or disconnecting a battery charger, igniting gases from the battery and causing an explosion and/or burns.

j. **Never use compressed air to clean a battery.**

Warning: Compressed air can cause gasses and residual acid to become airborne and get into eyes or mouth, or onto skin or parts of the vehicle.

k. **Never use a power washer to clean a battery.**

Warning: Using a power washer can force water into the battery, and the burner on the washer may ignite gasses escaping from the battery.

l. **Never lay any conductor across the battery terminals.**

Warning: Any conductor (such as a metal tool, wire, or vehicle part) laid across the battery terminals creates an uninsulated circuit that may result in a spark, causing gas from the battery to ignite, causing an explosion.

m. **Do not attempt to jump-start a battery that may be frozen.**

Warning: When temperatures are below the freezing point, the fluid in a discharged battery can freeze. Attempting to jump-start a frozen battery can rupture the battery or cause it to explode. You must bring the battery temperature above the freezing point before attempting a jump-start.

n. **When connecting jumper cables to a battery, connect the ground to the vehicle frame or engine as far as possible from the battery.**

Warning: If jumper cables accidentally touch each other, a spark may result which can cause the battery to explode. A short circuit may also result which will damage the vehicle's charging or computer system.

Objective 8

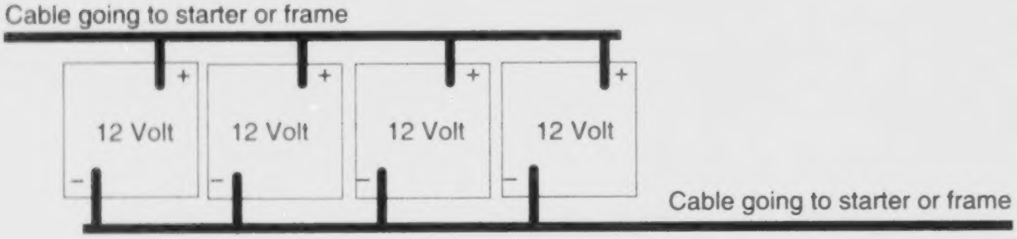
Connecting batteries in series, parallel, and series-parallel

a. **Parallel connection**

- 12-volt batteries in a 12-volt system

Note: When connecting positive terminals to positive terminals and negative terminals to negative terminals, amperage will increase, but voltage will stay the same.

Figure 10

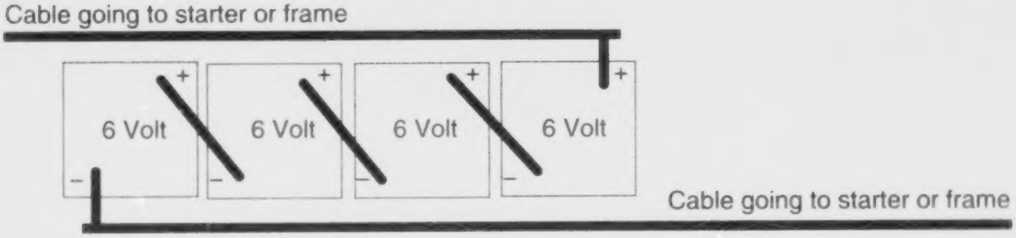

Cable going to starter or frame
+
+
+
+
12 Volt
12 Volt
12 Volt
12 Volt
−
−
−
−
Cable going to starter or frame

b. **Series connection**

- 6-volt batteries in a 24-volt system

Note: When connecting positive terminals to negative terminals, amperage will stay the same, and voltage will increase.

Figure 11

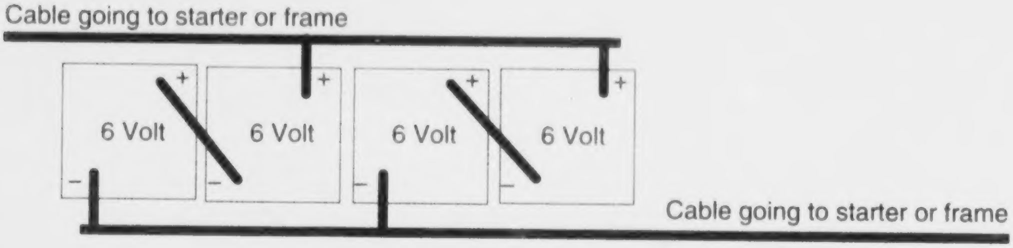

Cable going to starter or frame
+
+
+
+
6 Volt
6 Volt
6 Volt
6 Volt
−
−
−
−
Cable going to starter or frame

c. **Series-parallel connections**

- 6-volt batteries in a 12-volt system

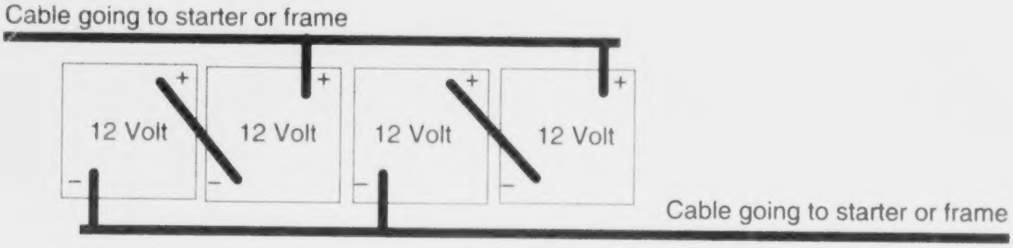
Note: When connecting batteries in series-parallel, voltage will increase between the two batteries in series, and amperage will stay the same. When batteries are connected in parallel with another set of batteries, amperage will increase but voltage will stay the same at that point.

Figure 12


Cable going to starter or frame
+
6 Volt
–
+
6 Volt
–
+
6 Volt
–
+
6 Volt
–
Cable going to starter or frame

- 12-volt batteries in a 24-volt system
  - Batteries connected in series-parallel

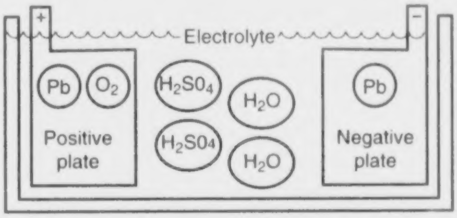
Figure 13


Cable going to starter or frame
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
Cable going to starter or frame

Student Supplement 1—How a Battery Works

A healthy battery is critical to the maintenance of proper voltage for all electrical uses in a vehicle. In order for you to make correct decisions about maintaining a battery, it is important for you to understand how a healthy battery works.

Figure 1


+
Electrolyte
-
Pb
O_2
H_2SO_4
H_2O
H_2SO_4
H_2O
Pb
Positive plate
Negative plate

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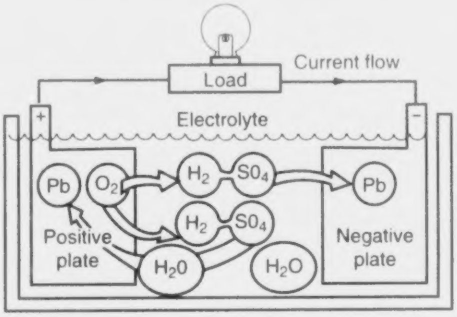
A battery is an electrochemical device that produces electricity. Although a vehicle battery is called a "storage" battery, it does not actually store electricity. Instead, it stores chemicals that can produce electricity. The charging process from the vehicle's generator causes the chemical reactions that can renew the stored chemicals.

Inside a battery, plates of two metals—lead (Pb) and lead peroxide (PbO_2) are suspended in a solution of sulfuric acid (H_2SO_4) and water (H_2O). (Figure 1)

The lead peroxide has a positive (+) charge, and the lead has a negative (-) charge. The water-sulfuric acid solution, called the electrolyte, carries the charge between the plates.

Figure 2


Load
Current flow
+
Electrolyte
-
Pb
O_2
H_2
SO_4
Pb
H_2
SO_4
Positive plate
Negative plate
H_2O
H_2O

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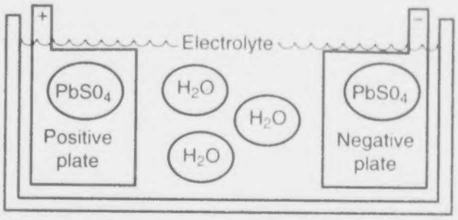
When the battery is discharging—releasing electricity to operate a load—the battery plates use the circuit to the load and the hydrogen, oxygen, and sulfur atoms in the electrolyte to transfer the electrons that make up the electrical charge. (Figure 2) The oxygen (O_2) in the positive plate combines with the hydrogen (H_2) in the sulfuric acid to form additional water (H_2O) molecules. The lead (Pb) in both the positive and the negative plates combines with the oxygen (O_2) and the sulfur (S) in the sulfuric acid to form lead sulfate ($PbSO_4$).

Figure 3



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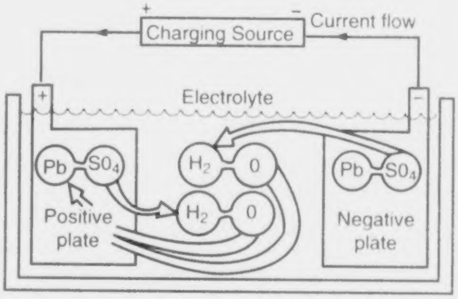
During discharging, both the positive and the negative plates form a coating of lead sulfate ($PbSO_4$), and the electrolyte solution becomes more and more plain water. When a battery is discharged (Figure 3), there is a complete coating of lead sulfate on both the negative and the positive plates, and the electrolyte is almost totally water.

Since voltage depends on the difference in charge between the two plates, as the plates become more and more similar, the battery is able to produce less and less voltage. If the lead sulfate on the plates becomes hard—as it would if the battery were stored for a long period of time, or if the plates are exposed when the water in the battery has evaporated—it becomes very difficult to remove. Sometimes such a battery cannot be recharged.

Figure 4



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When the battery is recharging from the generator, the process is reversed (Figure 4). As the generator applies current to the battery, the lead sulfate ($PbSO_4$) on both plates again reverts to pure lead (Pb) and lead peroxide (PbO_2). Some of the water (H_2O) splits into hydrogen (H) and oxygen (O_2).

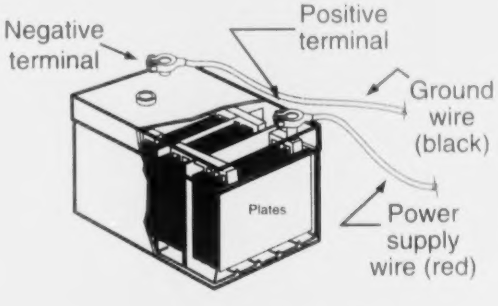
If you look inside a battery when it is recharging, you will see bubbles as the hydrogen and oxygen split. The hydrogen (H) combines with the (SO_4) to again become sulfuric acid (H_2SO_4). Some of the free oxygen released from the water combines with the lead on the positive plate to again form lead peroxide (PbO_2), and some of the oxygen leaves the battery as oxygen gas (O_2). It is these by-products (oxygen and hydrogen) of the charging process that increase the risk of sparking and explosions during charging.

Even correct recharging from the vehicle's generator never renews the electrolyte and the cell plates completely. Eventually the plates will wear out, and you will have to replace the battery. Vehicle battery electrolyte is usually made up of about 1/3 sulfuric acid and 2/3 water (by weight, not volume). Since it is oxygen from the water that is lost during charging, it is almost always additional water (not sulfuric acid) that is needed if the battery's electrolyte level is low. You can, however, purchase additional electrolyte commercially, and sometimes adding this can extend a battery's life.

Battery Construction

Typically, the 12-volt batteries used in most vehicles consist of six separate cells enclosed in a strong plastic case (Figure 5). Each cell contains 9-13 plates and its own supply of electrolyte. Each cell is designed to produce about 2.1-2.2 volts. The more plate surface area inside the battery, the larger the current capacity of the battery. (Plate surface is increased by making larger plates, more plates, or by designing the plates so they are porous, exposing more surface area.) Positive and negative plates alternate in the cell, separated by plate separators. The negative plates (made of lead) are joined together by connectors (or straps) and are attached to the negative battery terminal. The positive plates (made of lead peroxide) are similarly joined to the positive battery terminal.

Figure 5



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Objective 9

Assignment Sheet 1—Evaluate Factors in Selecting the Appropriate Battery for a Vehicle

Name ____________________ Overall Rating __________

Date ____________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 16 of the 20 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

When evaluating and selecting the appropriate battery for a vehicle, a number of factors must be considered. The battery must always have the appropriate voltage. Almost all vehicles use 12-volt batteries. Never use a battery with a voltage other than the one specified in the vehicle. A replacement battery must have a capacity equal to or higher than the original battery. Choosing a battery with less than the recommended capacity will cause starting problems and shorten battery life. Battery capacity is rated in cold cranking amps (CCA) and sometimes in reserve capacity.

Aftermarket electrical equipment on the vehicle adds additional current requirements from the battery. Such additional electrical requirements may necessitate the purchase of a battery with a capacity larger than that specified by the manufacturer. The approximate battery draw of some typical aftermarket accessories are listed below:

Table 1

Approximate Battery Draw of Vehicle Aftermarket Equipment

Equipment	Current Required
Cellular phone	2-4 amps
Stereo system	50-75 amps
Laptop computer	2-3 amps
Fog lights	7-10 amps
Global positioning system	5-7 amps

A replacement battery must have the same physical features as the battery being replaced. It must be the correct size to fit in the battery receptacle, and its terminals must be on the top or side in the same position as the old battery. The Battery Council International has classified batteries by case size, terminal placement, and polarity. Table 2 shows the BCI Group Size for common automotive batteries.

Assignment Sheet 1

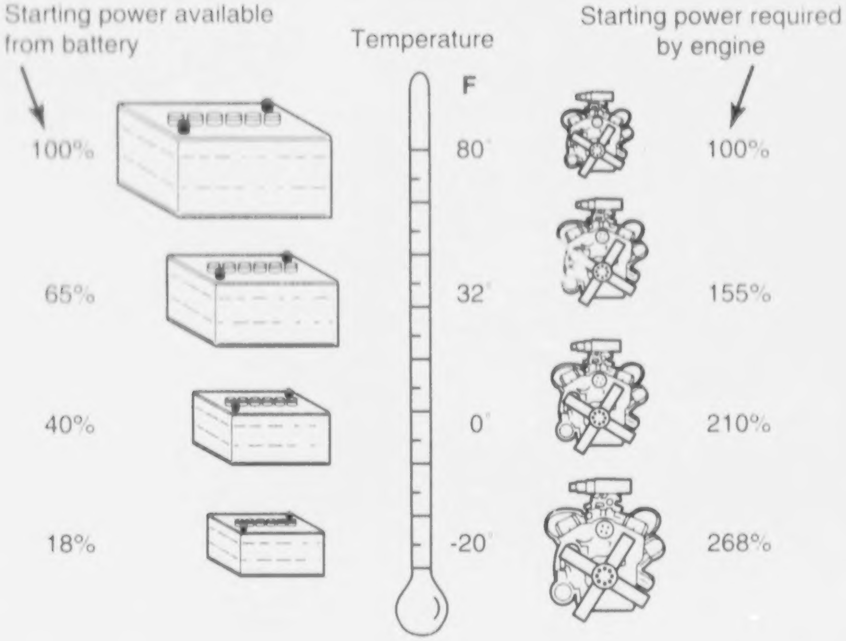
Table 2—**BCI Group Size for Common Batteries**

Note: Gel cell batteries are referenced with a "G" in front of the group size.

BCI Group Size	Max Dimensions						Performance Ranges	
	Length		Width		Height		CCA, Amps @ 0°F	RC, Minutes @ 80 F°
	in.	mm	in.	mm	in.	mm		
Side Terminal								
70	8.8	227.7	7.0	178.3	7.3	185.0	370-630	60-80
74	10.9	275.5	7.0	178.3	8.0	178.3	475-500	90-125
75	9.5	240.8	7.0	178.3	7.3	178.3	475	90-100
76	13.1	334.0	7.1	179.0	8.5	216.0	970-1075	150
78	10.0	275.6	7.0	178.3	7.3	185.0	550-770	95-115
79	12.1	306.3	7.0	177.6	7.3	186.0	880	140
70DT	8.8	222.7	7.0	177.5	7.9	202.4	450-675	70-80
78DT	10.9	275.6	7.0	177.5	7.8	201.0	875	115
Top Terminal								
24	10.9	275.5	6.8	173.0	8.8	222.8	400-950	90-125
24F	10.9	275.5	6.8	173.0	8.8	222.8	475-950	90-120
25	9.1	230.3	6.8	173.0	8.8	222.8	525-725	105-110
26	8.8	222.7	6.8	173.0	8.0	203.0	370-630	60-80
26R	8.8	222.7	6.8	173.0	8.0	203.0	370-630	60-80
31HCT	13.0	330.0	6.8	172.0	9.4	238.0	625	180
31-750	13.0	330.0	6.8	172.0	9.4	238.0	750	160
31-900	13.0	330.0	6.8	172.0	9.4	238.0	900	160
34	10.0	260.6	6.8	173.0	7.8	197.0	525-630	110-115
35	9.1	230.3	6.8	173.0	8.8	222.8	525-725	105-110
41	11.5	293.0	6.9	175.0	6.9	175.0	510-640	80-100
42	9.7	245.3	6.8	173.0	6.8	173.5	400-500	70
45	8.9	226.3	5.5	140.0	8.9	226.0	425-500	65-70
51	9.4	238.2	5.1	129.0	8.8	223.0	410	60
55	9.2	232.8	6.1	154.0	8.3	210.0	430-550	70-80
58	9.7	245.3	7.2	184.0	6.8	173.5	430-550	80-90
62	8.9	226.3	6.4	162.0	8.9	225.0	430-550	70-90
65	11.9	303.4	7.5	189.9	7.6	193.1	700-850	150-160
85	9.5	240.8	6.8	173.0	8.0	203.0	630	90-95

855

Figure 1


Starting power available from battery
Temperature
Starting power required by engine
F
100%
80°
100%
65%
32°
155%
40%
0°
210%
18%
-20°
268%

The starting power of a battery is affected by the outside climate. As Figure 1 shows, when the temperature goes down, two things happen which affect the starting power of the battery:

(1) More power is needed to start the engine.
(2) Less power is available from the battery.

So when it is cold outside, not only does it take more power to start the engine, but the battery has less power to give. A battery that works fine most of the year can be incapable of starting the engine when the weather gets cold. Starting the vehicle is the electrical task that requires the greatest amount of current from the battery, drawing as it does strictly from the electricity stored in the battery. Fortunately, this requirement is brief, ending once the engine is started.

Batteries lose their potency as they age. The date the battery is shipped from the factory is coded and attached to the battery or hot-stamped into the battery case along the top edge. A stands for January, B for February, and so on. (Some codes skip the letter I because it might be confused with the digit 1.) The next digit is a number that represents the year. For example, the code D8 means the battery was shipped in April, 1998. It's a good idea not to purchase a battery that was shipped more than 6 or 8 months ago.

Assignment Sheet 1

Directions

Review and use the information found in the Information Sheet and the introduction to the assignment sheet to answer to following questions. Write your answer in the blank provided.

____ 1. Technician A says that a vehicle battery operating when the weather is cold is weaker than the same battery operating when the weather is warm. Technician B says that vehicles operating in a cold climate need a larger capacity battery than vehicles operating in a warm climate. Who is right?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

____ 2. Can you harm a vehicle by using a battery with a capacity smaller than recommended?

YES NO (Circle One)

____ 3. Technician A says a BCI group rating is a national standard rating for the cold cranking amperes (CCA) needed for a replacement battery. Technician B says a BCI rating is a manufacturer's rating for the reserve capacity of a battery. Who is right?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

____ 4. In February 1998, the battery sent over for installation in a vehicle has the code E9 stamped onto its case. Technician A plans to install the battery in the vehicle. Technician B says the battery should be sent back and exchanged for a fresher battery. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

____ 5. What is the BCI number of a battery that is 8.8 in. long, 7 in. wide, and 7.9 in. high?

a. 26
b. 26R
c. 70
d. 70DT

___ 6. If you are planning to move to Alaska, you might want to choose a new battery that has a higher capacity. Which of the following would be appropriate to increase?

a. CCA rating
b. Voltage
c. BCI group rating
d. None of the above

___ 7. Technician A says it takes 18% of battery power to start a vehicle at -20°. Technician B says less battery power is needed for starting at lower temperatures. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

___ 8. Technician A says that using a laptop computer off the vehicle battery draws a lot more electricity than operating a cellular phone. Technician B says they both draw about the same amount. Who is right?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

___ 9. Which of the following ratings indicates a more reliable battery for starting a vehicle in cold weather?

a. 370 CCA
b. 410 CCA
c. 630 CCA
d. 430 CCA

___ 10. Technician A says that the BCI group size of a battery rated 880 CCA is 79. Technician B says that you have to know the reserve capacity of the battery also before you can tell the battery's group size. Who is right?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

___ 11. Under normal operating conditions, does a battery with a reserve capacity of 120 minutes perform better than one with a RC rating of 60 minutes?

YES NO (Circle One)

___ 12. Of batteries with the following reserve capacity, which will last the longest if the vehicle's charging system fails?

a. 45 min.
b. 60 min.
c. 90 min.
d. 120 min.

___ 13. Technician A says you must always install a replacement battery that is of equal or greater voltage than the one you remove. Technician B says that the battery voltage must always be identical to manufacturer's specifications. Who is right?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor Technician B

___ 14. Is a vehicle using a battery with a capacity smaller than recommended as reliable as one using a battery of recommended capacity?

YES NO (Circle One)

___ 15. What single task places the largest drain on the vehicle battery?

____

Questions 16-20 all apply to the following circumstances:

In November 1998, you are replacing a battery for a vehicle whose old battery has been discarded and is not available. You look up the size battery recommended for this vehicle and find that a 12 volt 400 CCA battery is recommended by the manufacturer. The battery receptacle is 8.9 in. long and 5.5 in. wide. The vehicle has a car phone and a high-output aftermarket stereo installed. The vehicle belongs to a customer living in Fargo, North Dakota where it is sometimes a long way between service stations.

You have several batteries to choose from as you select a replacement battery for this vehicle. What specification is your best choice in the categories given below?

___ 16. Voltage

a. 6 volt
b. 12 volt
c. 24 volt

___ 17. BCI group number

a. 26
b. 26R
c. 45
d. 70

__ 18. CCA

a. 325 CCA
b. 400 CCA
c. 425 CCA
d. 1000 CCA

__ 19. RC

a. 60 minutes
b. 80 minutes
c. 90 minutes
d. 120 minutes

__ 20. Date code

a. B8
b. F8
c. I7
d. J8

Objective 10

Job Sheet 1—Maintain and Restore Electronic Memory Functions

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Whenever you disconnect the battery for any reason, any functions that rely on the battery will automatically stop. Normally, this is no problem. However, there are memory functions that will be lost if voltage is stopped. These memory functions are for things such as the electric clock, station and volume settings on the radio, and settings for power seats, power mirrors, and the steering wheel. More and more vehicles, particularly upscale vehicles, have memory functions.

To protect such memory functions while the battery is disconnected, a memory keeper should be used. A memory keeper is a small battery that is attached to the vehicle's cigar lighter or power receptacle before the battery is disconnected. Then, when the battery is disconnected, the memory keeper supplies the system with a small amount of voltage—enough to maintain the vehicle's memory functions.

You can purchase an inexpensive memory keeper at most auto supply stores, but its construction is simple enough that you can make one yourself. To make a memory keeper, use two wires to attach a cigar lighter adapter to a small 9-volt battery.

It is important when using a memory keeper to remember not to turn on the engine or switch on any heavy electric loads. The 9-volt battery won't support such heavy loads. Not only will the engine not start nor the heavy loads function, but they will instantly deplete the voltage in the small battery.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 1

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Memory keeper
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn the engine off.

☐ 6. Plug the memory keeper into the cigar lighter.

☐ 7. Disconnect the vehicle's battery and perform necessary tests and/or service.

☐ 8. Reconnect the vehicle's battery after the service is complete.

☐ 9. Unplug the memory keeper before you start the engine.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ____

Address ____

Phone # ____

Date In ____

Date Out ____

JOB TICKET

Customer Name ____

Customer Address ____

Customer Phone # ____

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____

Services/repairs made: ____

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____ Date ____

Technician ____

Supervisor ____

Objective 11

Job Sheet 2—Inspect, Clean, Fill, and Replace a Battery, Battery Cables, Connectors, Clamps, Battery Box, and Hold Downs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	
• Safety procedures are followed	
• Service manual is used properly	
• Parts are inspected to specifications	
• Parts are serviced to specifications	
• Job ticket is filled out properly	
• Cleanup is adequate	

Basic Skills

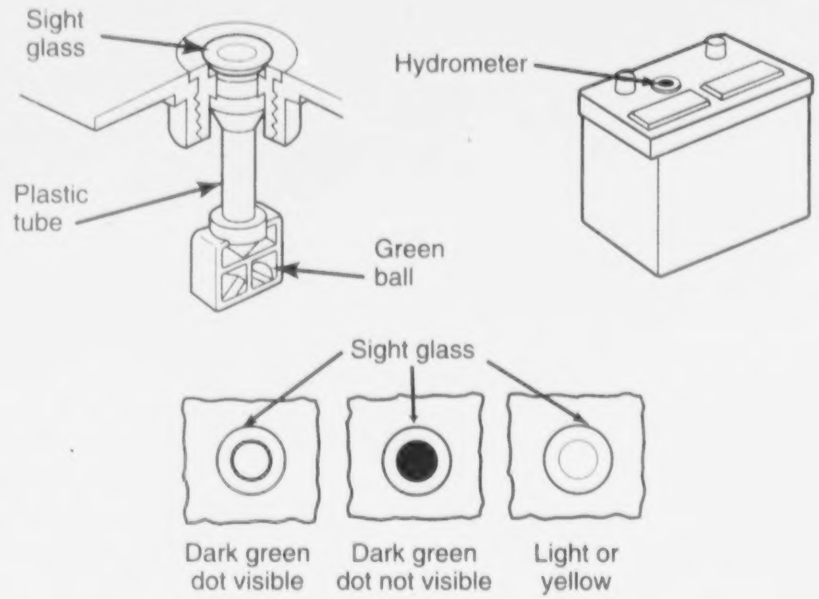
Reading   Science   Critical Thinking   Employability

Introduction

Vehicle batteries must be inspected and serviced to maintain long battery life, but a damaged or worn-out battery must be replaced. Preventive maintenance includes a visual inspection, cleaning, reconnection, and, if necessary, the replacement of the battery cables.

You check a battery's electrolyte level by removing the fill caps and looking into the cells. The electrolyte should cover all the battery plates inside each cell. If the electrolyte does not cover all the plates in a cell, you should add distilled water until the fluid covers the plates. Regular tap water contains minerals that can cause the cell plates to short out. Distilled water does not contain these impurities. Only use distilled water when you add water to the battery cells. You can also purchase electrolyte and add it instead of distilled water. Adding electrolyte instead of distilled water can prolong the life of the battery somewhat—particularly in an older battery.

Figure 1



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In a low-maintenance battery that has a built-in hydrometer, you check the battery by looking at the hydrometer on top of the battery. (Figure 1) If a green dot is visible in the sight glass, the electrolyte level is satisfactory, and the battery is adequately charged. If the sight glass is dark, the battery needs to be charged. If the sight glass is light yellow or clear, the electrolyte level is below the bottom of the test indicator. The battery may be worn out or the case may be tipped, broken, or cracked. Never try to charge a battery that shows yellow or clear; trying to charge it could make it explode. If the indicator is light yellow or clear, the battery must be replaced.

It may seem out of place to scrub the outside of the battery case, but this level of cleanliness has a direct link to the proper functioning of the vehicle's electric system. As a battery charges, the electrolyte inside the battery heats up to the point where it can overflow through the battery's vent holes onto the battery case. A stain of dried electrolyte on the battery case can create an artificial circuit between the battery terminals that can actually drain electricity from the battery. You can make a simple test to see if the battery is draining in this way. Connect the negative lead of a multimeter or volt-amp tester to the negative terminal of the battery and touch the top of the battery with the positive lead. If you can read any voltage, the electrolyte overflow is causing a battery drain.

Job Sheet 2

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Anticorrosion compound
- Appropriate replacement battery
- Battery carrier or lifting strap
- Battery clamp puller
- Box end wrench or special battery pliers
- Clean water
- Distilled water
- Flashlight
- Safety glasses
- Locking pliers or channel-lock pliers
- Masking tape
- New battery cables
- One quart baking soda and water solution (4 tablespoons of baking soda to 4 cups of water)
- Rubber apron
- Rubber gloves
- Scrub brush
- Shop towel
- Terminal cleaning tool
- Wire brush

Note: Procedures may vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Check the electrolyte level in a conventional battery or a low-maintenance battery with electrolyte access

> **Warning:** Batteries contain acid that could cause blindness. Wear eye protection when working around batteries.

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions to not have "park".

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☐ 5. Remove each filler cap.

> **Warning:** Batteries can explode if the gas produced in them is ignited. Keep all sparks and flame always from the battery.

☐ 6. Check the electrolyte level by looking into each vent, using a flashlight if necessary.

☐ 7. If the top of the battery plates can be seen above the level of the electrolyte, slowly add distilled water or electrolyte until the plates are fully covered.

Note: Tap water contains minerals which may cause the battery to short out. Only use distilled water to refill a battery.

☐ 8. Replace the filler caps.

☐ 9. Check to be sure the vent holes in the filler caps are open.

> **Warning:** Clogged vent holes can cause the battery to explode. Make sure the vent holes in the vent caps are kept open.

Procedure

Check the electrolyte level in a low-maintenance battery with a built-in hydrometer

☐ 1. Observe the color of the built-in hydrometer.

Note: If the hydrometer shows green or dark, the electrolyte level is sufficient.

☐ 2. Charge the battery if the hydrometer is dark.

☐ 3. Replace the battery if the hydrometer shows clear or light yellow.

> **Warning:** Hydrometers that show clear or light yellow may indicate a damaged battery case that will explode if charged. Never attempt to charge a battery whose hydrometer shows clear or light yellow.

Procedure

Inspect and disconnect the battery

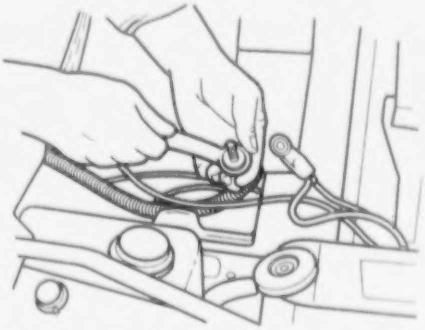
☐ 1. Examine the battery for:

- Signs of leakage (corrosion on the battery carrier, inner fender, or vehicle frame)
- Cracked case
- Missing vent or filler caps
- Loose or missing cable clamps
- Loose or damaged hold-downs

☐ 2. Check the battery terminals and cable clamps for corrosion. (Figure 2)

Note: Battery terminals, especially top-mounted terminal posts, tend to corrode. Corrosion builds up around the cable clamps and between the terminals and cable clamps.

Figure 2



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☐ 3. Disconnect the negative terminal clamp.

Note: Removing the positive terminal first can cause a voltage spike that will damage electronic circuits. Always remove the negative terminal before you remove the positive terminal.

☐ 4. On nut and bolt type clamps, use a box end wrench or special battery pliers to loosen the clamp nut about 3/8 inch; if the clamp is heavily corroded, use a clamp puller to remove the clamp from the terminal.

Note: On spring ring type clamps, squeeze the end of the rings apart with locking or channel-lock pliers.

☐ 5. Disconnect the positive terminal cable clamp following the procedures in step 4.

☐ 6. Examine both battery cables, starting at the battery and working to the other end. Look for:

- loose clamps or connections
- cut, scratched, or damaged insulation
- tight kinks or bends, which might indicate damaged conductors

☐ 7. If you find any of these problems, or other kinds of damage, the cable must be repaired or replaced.

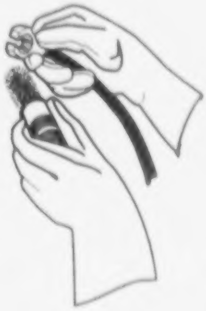
Note: You should not tape the cable insulation, or attempt to straighten out tightly kinked battery cables. When replacing battery cables, be sure to use cables of the same gauge and the same length or shorter length than the original cables. Always replace both battery cables at the same time.

Procedure

Clean the battery

☐ 1. Use a wire brush to clean the cable clamps until the metal looks shiny and bright. (Figure 3)

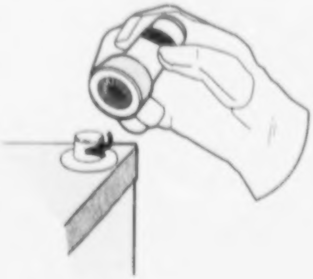
Figure 3



☐ 2. Use a terminal post cleaning tool or a wire brush to clean the terminal posts until the metal looks shiny and bright. (Figure 4)

Note: Particles of corrosion which fall on a vehicle or its parts can ruin the vehicle's paint and corrode other parts. Remove particles of corrosion completely.

Figure 4



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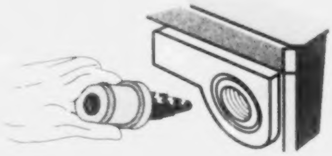
☐ 3. On side-mounted terminals, use a wire brush to clean both sides of the terminal clamps. (Figure 5)

Figure 5

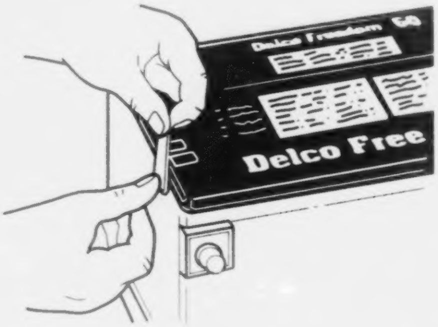


☐ 4. Use a wire brush to clean the terminal contact areas.

Note: Sometimes the battery is so corroded that it must be removed from the vehicle in order to be cleaned properly. If this is necessary, loosen the battery hold-downs and remove the battery from the vehicle before proceeding.

☐ 5. Tape the vent holes on the battery. (Figure 6)

Figure 6



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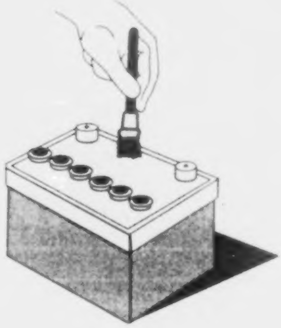
☐ 6. Brush a baking soda and water solution on the battery case, terminals, and cable clamps. (Figure 7)

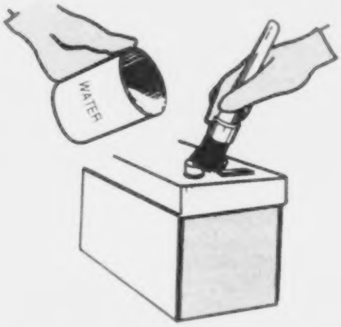
> **Warning:** If the baking soda and water solution is allowed to clog the battery vent holes, the resulting chemical reaction can cause pressure buildup and the possible spewing of electrolyte. Do not allow the baking soda solution to get into the vent holes.

Figure 7



☐ 7. When the baking soda solution stops foaming,wash the residue away with clean water and brush with a scrub brush to remove stubborn residue. (Figure 8)

Figure 8



☐ 8. Dry the battery, terminals, and cables with a clean shop towel.

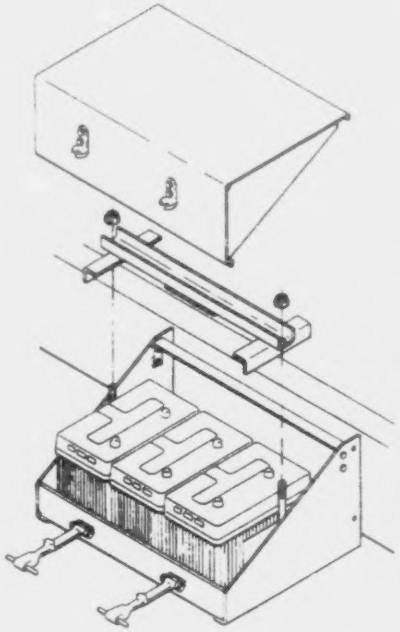
> **Warning:** Do not use an air hose to dry a battery. The air can pull the electrolyte out through the vent caps, spraying acid mixture over your body and the vehicle.

☐ 9. Remove the tape from the vent holes on the battery.

Procedure

Inspect battery box and hold-downs

Figure 9



Courtesy of Freightliner LLC

☐ 1. Inspect battery box for cracks, loose mounting bolts, and corrosion.

Note: If cracks are found, they should be evaluated for serviceability and repaired or replaced as needed.

☐ 2. Inspect hold-downs and mounting bolts for proper fit and effectiveness.

☐ 3. Clean any corrosion off the hold-downs and battery box with a mixture of baking soda and water.

Warning: Do not use an air hose to clean corrosion off the battery box or hold-downs. The compressed air can spray corrosion over your body and the vehicle.

☐ 4. When the baking soda solution stops foaming, wash the residue away with clean water and brush with a scrub brush to remove stubborn residue.

☐ 5. Inspect battery box drain to insure the hole is clear of debris.

☐ 6. Replace and tighten all mounting bolts as needed.

Job Sheet 2

Procedure

Replace the battery cables

☐ 1. Disconnect the old negative cable from the ground on the body.

☐ 2. Disconnect the old positive cable from the electrical system.

☐ 3. Clean the battery terminals.

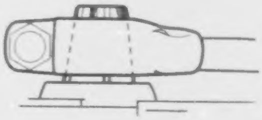
☐ 4. Connect a new positive cable to the electrical system.

☐ 5. Connect a new negative cable to the ground on the body.

☐ 6. If the battery has been removed from the vehicle for cleaning, reinstall it and tighten the hold-downs, being careful not to over tighten.

☐ 7. Reconnect the positive cable to the positive terminal, making sure the cable clamp is tight and in the correct position. (Figure 10)

Figure 10

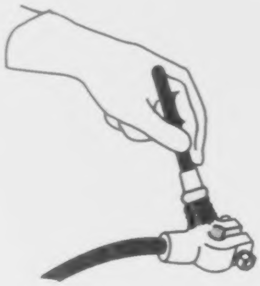


Note: Connecting the negative terminal first can cause a voltage spike that will damage electronic circuits. Always connect the positive terminal before you connect the negative terminal.

☐ 8. Reconnect the negative terminal cable, making sure the cable clamp is tight and in the correct position.

☐ 9. Spread or spray anticorrosion compound over the cable clamps and terminals. (Figure 11)

Figure 11



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Procedure

Replace the battery

☐ 1. If the battery cables are not marked, use a bit of masking tape to mark the positive and the negative cables before disconnecting them from the old battery.

☐ 2. Disconnect the battery negative terminal clamp.

Note: If the clamps are the nut and bolt type, remove them with a box end wrench or special battery pliers. Loosen the clamp nut about 3/8 inch. If the clamps are the spring ring type, remove them by squeezing the end of the rings apart with locking or channel-lock pliers.

Note: Removing the positive terminal first can cause a voltage spike that will damage electronic circuits. Always remove the negative terminal before you remove the positive terminal.

☐ 3. Disconnect the positive terminal clamp.

☐ 4. Remove the battery hold-downs.

☐ 5. Remove the battery using a battery carrier or lifting strap.

☐ 6. Install the replacement battery using a battery carrier or lifting strap.

☐ 7. Tighten the hold-downs securely.

☐ 8. Reconnect the positive cable to the positive terminal, making sure the connectors are even with, or slightly below, the tops of the posts.

Note: Connecting the negative terminal first can cause a voltage spike that will damage electronic circuits. Always connect the positive terminal before you connect the negative terminal.

☐ 9. Reconnect the negative cable to the negative terminal, making sure the connectors are even with, or slightly below, the tops of the posts.

☐ 10. Tighten the cable clamps, making sure they are on snugly.

☐ 11. Spread or spray anticorrosion compound over the cable clamps and terminals.

Note: If anticorrosion compound gets between the cable clamp and the terminal, circuits using a small amount of current (such as a clock circuit) will function, but the vehicle will not start. The best way to avoid this is to make sure the connections are snug and you use only a light coating of anticorrosion compound.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

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Objective 12

Job Sheet 3—Make a Battery State-of-Charge Test

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

A battery state-of-charge test checks the battery's electrolyte and plates. The results of this test combined with the results of a battery capacity test will tell you whether or not a battery needs to be replaced.

A battery contains a combination of sulfuric acid and water called electrolyte. The ratio of sulfuric acid to water is affected during charging, discharging, and recharging. The electrolyte weighs more than plain water because sulfuric acid is heavier than water. When a battery is fully charged, the sulfuric acid to water ratio of the electrolyte is at its maximum, and, therefore, the weight of the electrolyte is at its maximum. When the battery discharges, the sulfuric acid in the electrolyte moves from the electrolyte into the cell plates. As the acid leaves the electrolyte, the weight of the electrolyte decreases. Therefore, the weight of the electrolyte can be used as an indicator of the battery's state-of-charge:

- When the weight of the electrolyte is low, the battery's state-of charge is low.
- When the weight of the electrolyte is high, the battery's state-of charge is high.

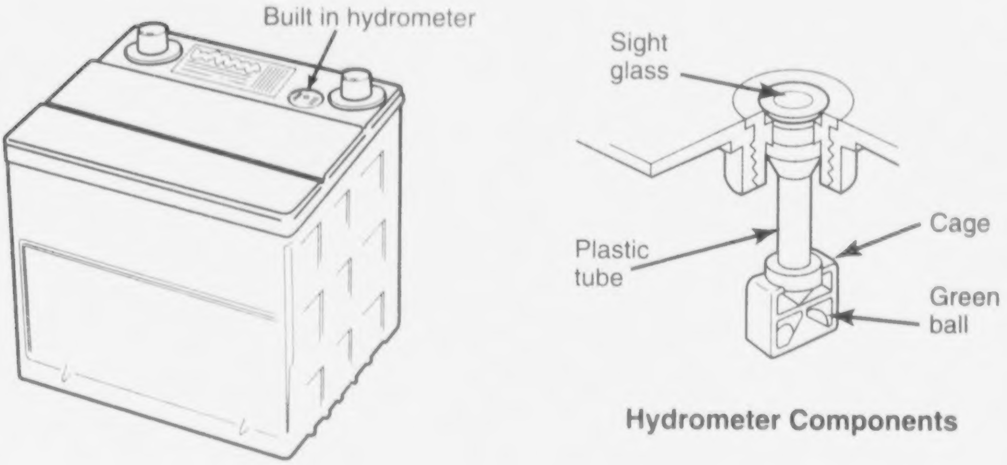
To determine the approximate state-of-charge of a battery, you need a scaled piece of equipment to measure the weight (called the specific gravity) of the electrolyte. The equipment used to measure specific gravity of electrolyte is called a hydrometer. However, to get an accurate reading from a hydrometer, one other principle must be considered:

- A change in temperature will change the specific gravity of electrolyte, which in turn affects the accuracy of the reading you will get from the hydrometer.

Eighty degrees Fahrenheit is the accepted electrolyte temperature standard for specific-gravity readings. This means that at an electrolyte temperature of 80°F, you can obtain an accurate specific gravity rating. But at temperatures higher than 80°F, there will be a loss in the specific gravity of the electrolyte caused by the expansion of the liquid as its temperature rises. And at temperatures lower than 80°F, there will be a gain in the specific-gravity of the electrolyte caused by the contraction of the liquid as its temperature falls. For this reason, the specific-gravity reading you obtain with a hydrometer is affected by electrolyte temperatures higher or lower than the standard, and this effect must be compensated for in order to obtain an accurate reading.

Low-Maintenance Batteries That Have Built-In Hydrometers

Figure 1



Hydrometer Components

Some low-maintenance batteries are designed with a special hydrometer that is built into the battery case (Figure 1). This type of hydrometer consists of a sight glass, a plastic tube that extends down into the electrolyte, a cage that is attached to the lower end of the rod, and a green ball that floats inside the cage. As the specific-gravity of the electrolyte changes, the green ball moves up and down inside the cage, and the state-of-charge is indicated by the changing appearance of the hydrometer's sight glass due to the rising and falling of the ball.

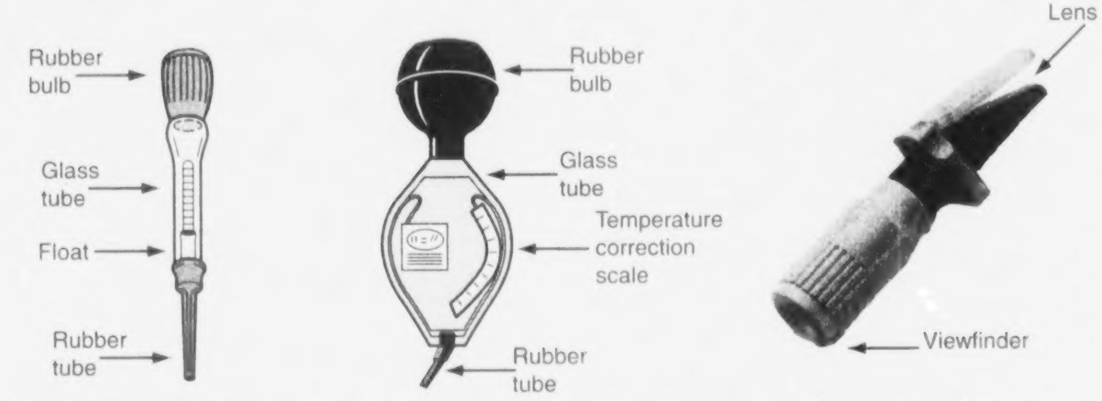
- When the green ball rises and touches the bottom of the rod, a green dot appears when you look into the hydrometer's sight glass. The green dot indicates that the battery's state-of-charge is 65% or greater. The battery is sufficiently charged for testing.
- When the battery's state-of-charge is below 65%, the green ball moves down into the electrolyte and rests at the bottom of the cage. The green dot disappears and the sight glass appears dark when you look into it. In this case, the battery must be slow-charged before further testing. (Job Sheet 6)

- If the electrolyte level in the battery drops below the lower end of the hydrometer cage, the sight glass appears clear or light yellow. A clear or light yellow sight glass indicates that the battery must be replaced.

Conventional Batteries and Low-Maintenance Batteries Without Built-In Hydrometers

Three common types of hydrometers are used for measuring the specific gravity of the electrolyte in batteries: non-compensating, temperature-compensating, and refractometer. (Figure 2)

Figure 2



Non-Compensating **Compensating** **Refractometer**

When using a non-compensating hydrometer, you must measure the temperature of the electrolyte and then perform a simple mathematical calculation to compensate for electrolyte temperatures above or below the 80°F standard.

For every 10 degrees of electrolyte temperature above 80°, four gravity points (.004) must be added to the hydrometer's specific gravity reading. For example, if you obtain a reading of 1.234 at 120°F, which is 40° above the standard (80°F), four points must be added for every 10°, a total addition of 16 gravity points (.016). The temperature-compensated reading would then be 1.250.

For every 10° of electrolyte temperature below 80°F, four gravity points must be subtracted from the hydrometer's specific gravity reading. For example, if you obtain a specific gravity reading of 1.282 at 0°F, four points must be subtracted for every 10° below the standard of 80°F. Therefore, a total deduction of 32 gravity points (.032) would be required, making a temperature-compensated reading of 1.250.

With temperature-compensating hydrometers, there is no need to make these calculations. They are designed with a floating ball-type device that expands and contracts with temperature changes and automatically gives a temperature-compensated reading.

A refractometer measures the refractive index of a liquid solution. Refractive index is the amount a light ray is bent when it passes through a solution in comparison to water. The denser the solution, the more the ray is slowed. When using a refractometer, the technician removes a drop of electrolyte from the cell of the battery and places it on the lens of the refractometer. Looking through the viewfinder, the technician will see a shaded area corresponding with a specific gravity reading. When using a refractometer, there is no need to compensate for temperature.

> **Warning**: Extreme care should be taken when using a refractometer because of the close proximity of electrolyte to the eye.

Once you have obtained a temperature-compensated specific gravity reading from each cell in the conventional battery, you can easily translate the reading into a battery state-of-charge percentage using a specific gravity/state-of-charge conversion chart. Table 1 is an example of a typical conversion chart.

Table 1

% Charge	**Specific Gravity (1.265 full charge)**
100%	1.265
95%	1.250
75%	1.230
50%	1.200
25%	1.170
Discharged	1.140

Use the table to determine the normal charged readings for cells in the type of battery you are working with and then compare each cell reading you recorded to the normal charged reading and all other cell readings.

The readings for all the cells must be —

- within the range given for normally charged cells of the battery type, and
- within 0.050 points of each other.

If the cell readings do not meet both of these requirements, you must charge the battery and then retest the battery's state-of-charge. If the cell readings still do not meet these requirements, you must replace the battery.

You should not check a battery's state-of-charge immediately after adding distilled water to the battery. To obtain an accurate measurement, make the check before distilled water is added. If the water level is too low to obtain a sample, add water as needed. Then after the battery has been operated long enough to thoroughly mix the water with the electrolyte, check the state of charge as you would normally.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Conventional battery
- Specific gravity/state-of-charge chart
- Safety glasses
- Hydrometer
- Pencil and paper
- Rubber apron
- Rubber gloves
- Shop towels

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Make a state-of-charge test on a conventional battery

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Perform a visual inspection of the battery; clean the battery if necessary.

☐ 6. Remove the battery filler caps.

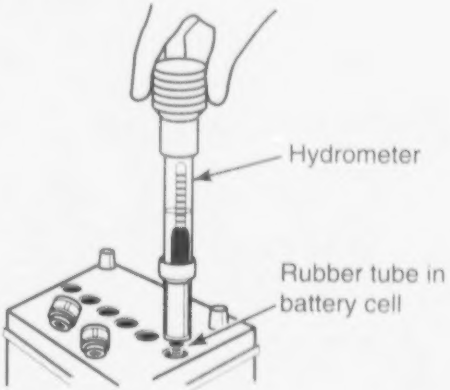
☐ 7. Squeeze the hydrometer bulb.

☐ 8. Insert the rubber hydrometer tube into the electrolyte in the filler hole over the first battery cell.

☐ 9. Slowly release the rubber bulb to draw the proper amount of electrolyte into the hydrometer. (Figure 3)

Note: Do not lift the hydrometer out of the electrolyte.

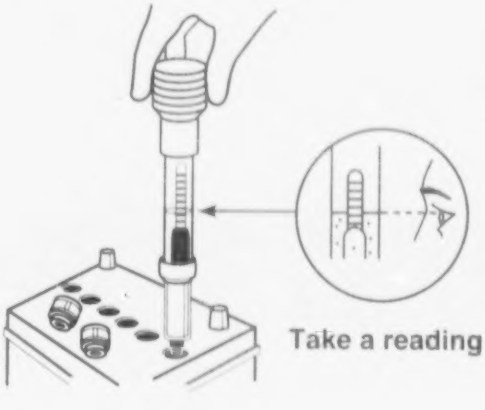
Figure 3



☐ 10. Check to be certain that the hydrometer is clean and functioning properly: the float should be suspended in the electrolyte; it should not bump the top of the hydrometer tube or stick to the side.

☐ 11. Holding the hydrometer level, bend down until you are at eye level with the hydrometer scale and take a reading. (Figure 4)

Figure 4



Take a reading at eye level.

☐ 12. Record the reading.

☐ 13. Squeeze the bulb to return the electrolyte to the cell.

☐ 14. Repeat steps 3 through 9 for each battery cell.

☐ 15. Replace the filler caps

☐ 16. If you used a non-compensating hydrometer, adjust the readings for temperature and record them.

☐ 17. Interpret the test results by checking the specific gravity chart to determine the battery state-of-charge percentage.

☐ 18. If the cell readings are all within the range given for normally charged cells of the battery type you are measuring, and all are within 0.050 points of each other, record the state-of-charge reading, clean the battery, and return it to service.

☐ 19. If the cell readings do not meet both requirements in step 17, record the state-of-charge reading, slow-charge the battery (Job Sheet 6), and then retest the state-of-charge.

Procedure

Make a state-of-charge test on a low-maintenance battery with a built-in hydrometer

☐ 1. Perform a visual inspection of the battery; clean the battery if necessary.

☐ 2. Look in the battery's built-in hydrometer.

☐ 3. If the sight glass shows green, the battery is sufficiently charged for testing.

☐ 4. If the sight glass shows black, slow-charge the battery (Job Sheet 6) before making further tests.

☐ 5. If the sight glass shows clear or yellow, replace the battery.

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

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Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 13

Job Sheet 4—Make a Battery Capacity (load) Test

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

A battery capacity test (sometimes called a load test or a high-rate discharge test) is useful because it measures the battery's ability to deliver current while working under a load. A good battery will produce current equal to 50% of its cold-cranking amp rating for 15 seconds while providing minimum voltage needed to start the engine.

A capacity test can be performed with various types of test equipment, but the equipment most commonly used is a volt-amp tester. The volt-amp tester combines an ammeter and a voltmeter with a resistance unit (load) that is adjusted with a load control knob. There are many different brands of quality volt-amp testers, although the ones most commonly referred to are the VAT 40 and VAT 60.

During use, the volt-amp tester leads are connected to the battery terminals, and then the load-control knob is turned, adjusting the load placed on the battery until a specified current shows on the ammeter. The voltmeter is then read to obtain a measure of the battery's voltage after the load has been maintained for 15 seconds.

The following procedure provides safety guidelines and outlines the steps typically used in making a battery capacity test. You must follow all general safety rules for dealing with batteries. Study the manufacturer's instructions before operating the tester used in your shop. To find out how much load to place on a battery when you make a battery capacity test, you can check the vehicle's service manual for specifications, or you can look on the battery case and locate the cold cranking amp rating of the battery. The suggested load for a capacity test on a battery is usually one-half the battery's cold cranking amps rating. For example if the battery is rated at 550 CCA, the load for a capacity test on that battery should be 275 amps.

Job Sheet 4

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Battery and battery manufacturer's specifications
- Safety glasses
- Glass thermometer
- Pencil and paper
- Post adapters (if the battery terminals are side-mounted)
- Rubber apron
- Rubber gloves
- Volt-amp tester and manufacturer's operating instructions
- Watch, clock, or timer
- DVOM

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Make a battery capacity test

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Perform a visual inspection of the battery; clean the battery if necessary. (Job Sheet 2)

☐ 6. Follow the volt-amptester manufacturer's instructions for preparing the tester for a capacity test and for connecting the tester leads to the battery terminal posts. (Table 1)

> **Warning:** Connecting or disconnecting the tester leads to the battery in any sequence other than the one recommended by the tester manufacturer can cause the battery to explode. Follow manufacturer's instructions in connecting and disconnecting the tester leads.

Note: Voltage measurement should be taken using an external DVOM or using the external voltmeter leads on the volt/amp tester.

☐ 7. Read the voltage on the volt-amp tester. If the voltage is not at least 12.4 volts or higher, charge the battery before making a capacity test.

☐ 8. Refer to the appropriate service manual or locate the battery's cold cranking amp (CCA) rating printed on the battery case to determine the correct load to place on the battery being tested.

Note: Some manufacturers provide specific load rates for their batteries; other manufacturers recommend that the load equal three times the battery's ampere-hour rating or one-half the cold-cranking amp rating.

☐ 9. If the battery has recently been charged, remove the surface charge from the battery by turning the load control knob until the specified load has been placed on the battery for 15 seconds; then immediately turn the knob back to the OFF position.

Warning: Applying load to the battery for more than 15 seconds will overheat the test equipment. Do not apply load to the battery for more than 15 seconds.

☐ 10. Wait 15 seconds and then turn the load control knob until the specified load (Step 8) has been placed on the battery for exactly15 seconds.

Note: Do not exceed 15 seconds.

☐ 11. Quickly note the voltage indicated on the voltmeter and immediately turn the control knob to the OFF position.

☐ 12. Record the voltmeter reading.

☐ 13. If the battery has vent caps or filler caps, remove a cap and take the temperature of the electrolyte in one of the center two cells.

☐ 14. Leave the electrolyte thermometer in the electrolyte until the temperature remains the same for about a minute.

☐ 15. Remove the thermometer and record the temperature.

☐ 16. Replace the vent cap.

☐ 17. If the battery does not have vent caps, estimate the battery's temperature by taking into consideration not only the temperature of the area where the battery has been in the hours just before the test, but how hot or cold the battery case feels to the touch.

☐ 18. Record the estimated temperature.

☐ 19. Interpret the capacity test results by comparing the voltage and temperature readings to the service manual, the battery manufacturer's specifications, or to Table 1.

Table 1

Electrolyte Temperature F°	**70+**	**60-69**	**50-59**	**40-49**	**30-39**	**20-29**	**10-19**	**0-9**
Minimum Voltage (12 volt battery)	9.6	9.5	9.4	9.3	9.1	8.9	8.7	8.5

☐ 20. If the voltage is at or higher than the minimum specified, the battery is good. Clean and charge the battery (Job Sheet 5) as necessary before returning it to service.

☐ 21. If the voltage reading is below the minimum specification, keep the volt-amp tester connected to the battery and wait 10 minutes.

☐ 22. At the end of that time, look at the voltage reading on the volt-amp tester again.

☐ 23. If the voltage has not risen to the minimum specification of 12.4 volts or higher, perform the 3-minute charge test in Job Sheet 5.

☐ 24. Follow the volt-amp tester manufacturer's instructions for disconnecting the tester from the battery.

☐ 25. Turn in job ticket when finished.

☐ 26. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 4

Objective 14

Job Sheet 5—Determine Battery State-of-Charge Using an Open Circuit Voltage Test

Name ________________ Attempt Number ______

Date ________________ Overall Rating ______

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Conventional battery and manufacturers specifications-12 volt
- Adjustable, fast-rate battery charger
- Battery capacity tester/volt-ohm meter
- Appropriate conductors
- Safety glasses
- Rubber gloves
- Carbon pile
- Rubber apron

Procedure

Note: Some battery manufacturers do not recommend the three-minute charge test. Do not use this on maintenance-free batteries. Follow the instructions for the battery you are testing.

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Remove the surface charge from the battery by using **one** of the two methods listed below.

Note: The battery's surface charge must bemoved if the battery has just been charged by either the vehicle's charging system or by an external charger.

- Crank the engine for 15 seconds without allowing the engine to start. Wait 10 to 15 minutes to allow battery voltage to stabilize.
- Using an adjustable carbon pile, place a load of one half the Cold Cranking Amps (CCA) on the battery for 15 seconds, then wait one minute.

☐ 6. Connect the volt-ohm meter across the battery terminals and oberve the reading.Compare your reading to table 1 to determine the battery's state-of-charge.

Table 1

Open Circuit Voltage

Open Circuit Voltage	State of Charge
12.6 or greater	100%
12.4 to 12.6	75-100%
12.2 to 12.4	50-75%
12.0 to 12.2	25-50%
11.7 to 12.0	0-25%

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name

Address

Phone #

Date In

Date Out

JOB TICKET

Customer Name

Customer Address

Customer Phone #

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested:

Services/repairs made:

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

Date

Technician

Supervisor

Objective 15

Job Sheet 6—Slow and Fast Charge a Battery

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

Normally, the vehicle's charging system will keep the battery adequately charged. However, sometimes a battery will lose its charge and not have enough power to start the vehicle. In fact, not being able to start the vehicle is usually the first sign that the battery is dead (discharged). Several things can cause a dead battery:

- Unintentional drain on the battery (such as leaving the lights on)
- Defective charging system
- Diluted electrolyte solution
- Incorrect battery for the application
- A sulfated battery

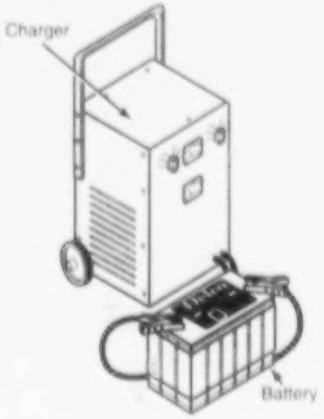
Note: A sulfated battery is one in which a chemical action inside the battery interferes with the battery's ability to accept a charge. Sulfation occurs as a battery ages. Storing a discharged battery will speed up sulfation.

Regardless of the cause, the battery must be recharged if possible. There are two ways to recharge the battery—slow charging and fast charging. Slow charging will charge the battery fully and minimize any possible damage to the battery; but it takes time—sometimes a full day or more. Fast charging will charge the battery quickly—under two hours—but it will not charge the battery fully and you must monitor the charging time and current carefully to avoid damaging the battery.

Fast Charging

To save repair time, most technicians choose to fast charge the battery, get it started, and allow the vehicle's charging system to recharge it fully during normal vehicle operation. A fast charger (Figure 1), sometimes called a quick or boost charger, forces a high amount of current (usually above 40-50 amps) into the battery for rapid recharging. Although you can fast charge a battery relatively quickly, you must constantly monitor the charging process to make sure the battery is not damaged and safety hazards are avoided.

Figure 1



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- Do not fast charge a battery that has been sitting for a long period of time or is totally discharged. Such a battery may be sulfated and charging a sulfated battery, can cause excessive gassing, boiling, and heat.
- Do not allow the temperature of the electrolyte to exceed a temperature of 125° F during charging. Excessive heat can boil the electrolyte and warp the battery plates. Some fast charger's are equipped with an automatic shut off should the temperature reach 125°F.
- Excessive fast charging can damage the battery.
- Do not allow the voltage of a 12-volt battery to exceed 15.5 volts.

Slow Charging

Slow charging is the safest and most effective way to charge a battery and is the recommended method. Slow charging renews the chemical makeup of the materials inside the battery and minimizes the chance of damaging or overcharging the battery. It is the only way to recharge a completely discharged battery. Unfortunately, it usually takes much longer than fast charging. But, if time permits, it is the method that should be used. A slow charger, or trickle charger, typically charges at 2-10 amps.

Determining Charging Rate and Time

Whenever you charge the battery, you must make two decisions: (1) the amount of current you will deliver to the battery (the charge rate) and (2) the amount of time you deliver that current. For example, if you set a charger to deliver a 10 amp charge for seven hours, you will deliver a 70-ampere-hour (AH) charge to the battery. You could also deliver the same 70 AH charge by choosing a charger setting of 5 amps and allowing the battery to charge for 14 hours.Several factors determine the best charging rate and time:

- The battery's size or electrical capacity in ampere-hours

  Note: A completely discharged 70 AH battery requires almost twice the recharging time as a completely discharged 40 AH battery.

- The temperature of the battery's electrolyte

  Note: It takes about two hours longer to charge a battery with an electrolyte temperature of 0°F than one of 80°F.

- The battery's state of charge

  Note: A completely discharged battery requires twice as much charge as a battery that is half discharged.

- The battery's age and condition

  Note: A battery that has seen much service or has been recharged many times will require a higher rate of charge for a longer time than will a relatively new battery or one that has not been recharged.

- The battery type

  Note: Low-maintenance batteries usually require a longer, more rapid rate of charge than conventional batteries. Many charger's have a switch to allow you to adjust for the type of battery being charged.

It is not always easy at first to know what setting you should make on the charger or how long to charge a battery. Several methods are commonly used. But the important thing to remember is that whether your goal is to charge the battery quickly to allow the vehicle to start or whether you want to charge the battery fully, you should always charge the battery safely and without damaging the battery.

Job Sheet 6

The Battery Council International gives the following battery charging recommendations based on the reserve capacity rating of the battery:

Table 1

Charging Table
Recommended rate and time for fully discharged condition

Battery Capacity (Reserve Minutes)	Slow Charge	Fast Charge
80 minutes or less	10 hrs. @ 5 amps 5 hrs. @ 10 amps	2.5 hrs. @ 20 amps 1.5 hrs. @ 30 amps
Above 80 to 125 minutes	15 hrs. @ 5 amps 7.5 hrs. @ 10 amps	3.75 hrs. @ 20 amps 1.5 hrs. @ 50 amps
Above 125 to 170 minutes	20 hrs. @ 5 amps 10 hrs. @ 10 amps	5 hrs. @20 amps 2 hrs. @ 50 amps
Above 170 to 250 minutes	30 hrs. @ 5 amps 15 hrs. @ 10 amps	7.5 hrs. @ 20 amps 3 hrs. @ 50 amps

Used with permission of Battery Council International.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Vehicle
- Battery charger and its operating instructions
- Appropriate replacement battery–12 volt
- Clock, watch, or timer
- Digital volt-ohmmeter
- Flashlight or shop light
- Safety glasses
- Hydrometer
- Rubber apron
- Rubber gloves
- Thermometer
- Volt-amp tester

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

9.0

Procedure

Fast charge a battery

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disconnect the negative (black) battery cable from the battery.

Note: Charging the battery with the negative battery cable connected may damage vehicle computers. Disconnect the negative battery cable before charging the battery.

☐ 6. Open the filler caps on the battery.

☐ 7. Use a flashlight or shop light to check the electrolyte inside the battery for ice crystals.

Warning: Attempting to charge a frozen battery can cause it to explode. Allow a frozen battery to warm for several hours before attempting to charge it.

☐ 8. Use a thermometer to measure the temperature of the electrolyte.

Note: If you cannot access the electrolyte, look for ice crystals through the battery case and feel the case to determine its approximate temperature.

☐ 9. If the battery is cold (under 60°F) or if there are ice crystals in the electrolyte, allow the battery to warm up for a few hours until the temperature of the electrolyte is 60°F or above.

☐ 10. Replace the filler caps.

☐ 11. Turn on the digital volt-ohmmeter and select the correct scale to measure 12-13 volts.

☐ 12. Connect the positive (red) lead to the positive battery terminal.

☐ 13. Connect the negative (black) lead to the negative battery terminal.

☐ 14. Compare the open circuit voltage showing on the DVOM with the following chart.

Table 2

Open Circuit Voltage

Open Circuit Voltage	State of Charge
12.6 or greater	100%
12.4 to 12.6	75-100%
12.2 to 12.4	50-75%
12.0 to 12.2	25-50%
11.7 to 12.0	0-25%

☐ 15. If the open circuit voltage is 11.7 or less, the battery is totally discharged. DO NOT FAST CHARGE THE BATTERY. Slow charge the battery instead.

☐ 16. Turn off the DVOM.

☐ 17. Remove the negative (black) lead from the DVOM to the positive battery terminal.

☐ 18. Remove the positive (red) lead from the DVOM to the positive battery terminal.

☐ 19. Make sure the battery charger is turned off.

☐ 20. Connect the positive (red) charger lead to the positive terminal of the battery.

☐ 21. Connect the negative (black) charger lead to the negative terminal of the battery.

☐ 22. Turn the charger to the FAST charge setting.

Note: The FAST charge setting usually delivers about 40-50 amps of current.

☐ 23. Use the method recommended in the battery charger manual or by your instructor to calculate the amount of time to set on the battery charger or use the method below:

  ☐ a. If the open circuit voltage you measured in step 13 shows the battery has a state of charge greater than 50%, set the charger for 1/2 hour.

☐ b. If the open circuit voltage you measured in step 13 shows the battery has a state of charge less than 50%, set the charger for 1 hour.

☐ 24. Turn on the battery charger.

☐ 25. In 15 minutes, remove a filler or vent cap and insert a thermometer into a battery cell and take an electrolyte temperature reading. Replace the filler cap.

Note: If you cannot take a temperature reading of the electrolyte, place the thermometer on the side of the battery case for 1 or 2 minutes, then read the temperature.

☐ 26. If the electrolyte temperature exceeds 125°F, reduce the charging rate and continue to recheck every 15 minutes until the electrolyte temperature is under 125°F.

☐ 27. At the end of the charge time, turn off the battery charger.

☐ 28. Disconnect the negative (black) cable between the charger and the battery.

☐ 29. Disconnect the positive (red) cable between the charger and the battery.

☐ 30. Reconnect the negative (black) battery cable.

☐ 31. Start the vehicle.

☐ 32. Be sure to allow the vehicle's engine to run for 15-20 minutes before you turn off the engine to allow the generator to recharge the battery.

☐ 33. Proceed to the next procedure or Job Sheet as directed by your instructor.

Procedure

Slow charge a battery

☐ 1. Disconnect the negative (black) battery cable from the battery.

Note: Charging the battery with the negative battery cable connected may damage vehicle computers. Disconnect the battery cable before charging the battery.

☐ 2. Disconnect the positive (red) battery cable from the battery.

☐ 3. Open the filler caps on the battery.

☐ 4. Use a flashlight or shop light to check the electrolyte inside the battery for ice crystals.

> **Warning:** Attempting to charge a frozen battery can cause it to explode. Allow a frozen battery to warm for several hours before attempting to charge it.

☐ 5. Use a thermometer to measure the temperature of the electrolyte.

Note: If you cannot access the electrolyte, look for ice crystals through the battery case and feel the case to determine its approximate temperature.

☐ 6. If the battery is cold (under 60°F) or if there are ice crystals in the electrolyte, allow the battery to warm up for a few hours until the temperature of the electrolyte is 60°F or above

☐ 7. Replace the filler caps.

☐ 8. Turn on the digital volt-ohmmeter and select the correct scale to measure 12-13 volts.

☐ 9. Connect the positive (red) lead to the positive battery terminal.10.

☐ 10. Connect the negative (black) lead to the negative battery terminal.

☐ 11. Compare the open circuit voltage showing on the DVOM with the following chart.

Table 3

Open Circuit Voltage

Open Circuit Voltage	State of Charge
12.6 or greater	100%
12.4 to 12.6	75-100%
12.2 to 12.4	50-75%
12.0 to 12.2	25-50%
11.7 to 12.0	0-25%

☐ 12. Turn off the DVOM.

☐ 13. Remove the negative (black) lead from the DVOM to the negative battery terminal.

☐ 14. Remove the positive (red) lead from the DVOM to the positive battery terminal.

☐ 15. Make sure the battery charger is turned off.

☐ 16. Connect the positive (red) charger lead to the positive terminal of the battery.

☐ 17. Connect the negative (black) charger lead to the negative terminal of the battery.

☐ 18. Turn the charger to the SLOW charge setting.

Note: The SLOW charge setting usually delivers about 2-10 amps of current.

☐ 19. Use the method recommended in the battery charger manual or by your instructor to calculate the amount of time to set on the battery charger.

Note: The average amount of time for slow-charging a battery is about 12-16 hours.

☐ 20. Turn on the battery charger.

☐ 21. About 2 hours before the time you have set is complete, remove a filler cap and use a hydrometer to measure the specific gravity of the electrolyte.

☐ 22. Compare the specific gravity reading to the following chart.

Table 4

% Charge	Specific Gravity (1.265 full charge)
100%	1.265
95%	1.250
75%	1.230
50%	1.200
25%	1.170
Discharged	1.140

☐ 23. If you cannot access the electrolyte, use the following alternate method:

  ☐ a. Turn off the battery charger.

  ☐ b. Connect the volt-amp tester following manufacturer's instructions for connecting the tester leads to the battery terminal posts.

- ☐ c. Apply a load of 100 amps to the battery to remove the surface charge on the battery.
- ☐ d. Disconnect the volt-amp tester from the battery.
- ☐ e. Connect a digital volt-ohmmeter following steps 8-10 above.
- ☐ f. Measure the open circuit voltage.
- ☐ g. Compare the open circuit voltage to Table 3.

☐ 24. Use the percentage of charge you found (using either method) to adjust the time setting on the charger as necessary. (Set more time if the state of charge is still low, less time if the state of charge is close to 100%.)

☐ 25. Continue charging, taking specific gravity readings (or open circuit voltage readings) as appropriate. Your specific gravity readings should become more frequent as the battery nears being 100% charged.

☐ 26. When 3 successive specific gravity readings (or open circuit voltage readings), taken at 1 hour intervals, show that the battery is 100% charged, stop charging the battery.

☐ 27. Turn off the charger.

☐ 28. If you have connected a DVOM to the battery terminals, disconnect the leads (disconnecting the negative lead first) to the DVOM and turn it off.

☐ 29. Disconnect the negative (black) cable between the charger and the battery.

☐ 30. Disconnect the positive (red) cable between the charger and the battery.

☐ 31. Reconnect the positive (red) battery cable.

☐ 32. Reconnect the negative (black) battery cable.

☐ 33. Turn in job ticket when finished.

☐ 34. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

Job Sheet 6

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________

Address ____________

Phone # ____________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________

Customer Address ____________

Customer Phone # ____________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________

Services/repairs made: ____________

	LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________ Date ____________

Technician ____________

Supervisor ____________

Objective 16

Job Sheet 7—Diagnose Parasitic (Key-Off) Battery Drain Problems

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedure followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

One of the most common problems associated with battery failure is parasitic draw. Parasitic draw drains a battery of its charge after the vehicle has been shut off. The driver may shut the vehicle off at the end of the day, and the next morning it may not start. Parasitic draw can result from many different problems. Accessories may inadvertently be left on, a defective switch may not shut off, or there could be some kind of electronics problem. Electrical/electronics technicians must be able to diagnose and repair parasitic draw problems.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- High-capacity amp meter (10-amp minimum)
- Volt-amp meter and manufacturer's operating instructions
- Battery terminal clamp puller
- Safety glasses
- Rubber apron
- Rubber gloves

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Check the vehicles automatically switched lamps and other accessories to insure they are off. Observe lockout/tagout procedures.

☐ 6. Disconnect the negative battery terminal.

☐ 7. Connect the high-capacity ammeter between the negative battery cable and the negative post on the battery to put the ammeter in series with the system.

> **Warning:** A high-capacity ammeter must be used to determine if a high current draw is above 10 amps. If a low-capacity ammeter is used, the ammeter could be severely damaged or at a minimum, blow a fuse.

☐ 8. Read amperage on the volt-amp tester. If the voltage is greater than 1 amp, current draw is excessive.

Note: If current draw is less than 1 amp, parasitic draw is not excessive.

☐ 9. While monitoring the volt-amp meter, remove one fuse at a time and note any changes on the volt-amp meter.

☐ 10. If current draw returns to normal after removing a fuse, note which accessory or accessories are controlled by that fuse.

☐ 11. Repair as needed.

☐ 12. Recheck to see if the problem has been eliminated.

☐ 13. Disconnect the volt-amp meter and reconnect the negative battery terminal.

☐ 14. Turn in job ticket when finished.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name

Address

Phone #

Date In

Date Out

JOB TICKET

Customer Name

Customer Address

Customer Phone #

Vehicle/Equip	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested

Services/repairs made

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost

Date

Technician

Supervisor

Objective 17

Job Sheet 8—Connect Batteries in Series, Parallel, and Series-Parallel

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Drawings are accurate	______
• Batteries are connected correctly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

Because batteries play such an important part in the operation of a vehicle, they become fatigued and need to be replaced. Multiple batteries may be connected in one of three ways: series, parallel, or series-parallel. Electrical/electronics systems technicians must be able to identify which configuration batteries are in, and install new batteries to the correct configuration.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Volt-ohm meter
- 6- or 12-volt batteries (4), or mock-up
- Battery terminal clamp puller
- Safety glasses
- Rubber apron
- Rubber gloves

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Using the diagrams below, draw lines to show the installation of battery cables in each of the four configurations.

Figure 1

a. 6-volt batteries

— 12-volt system

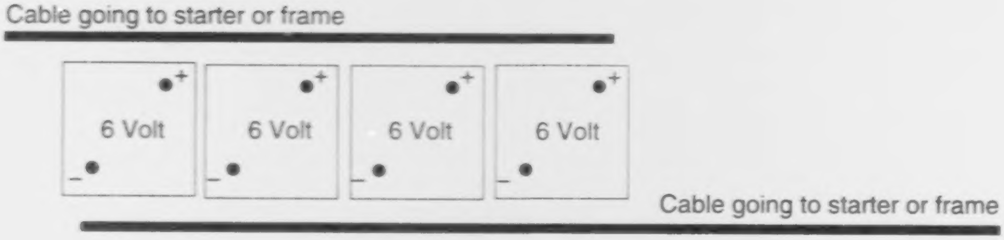

Cable going to starter or frame
+
6 Volt
−
+
6 Volt
−
+
6 Volt
−
+
6 Volt
−
Cable going to starter or frame

Figure 2

— 24-volt system

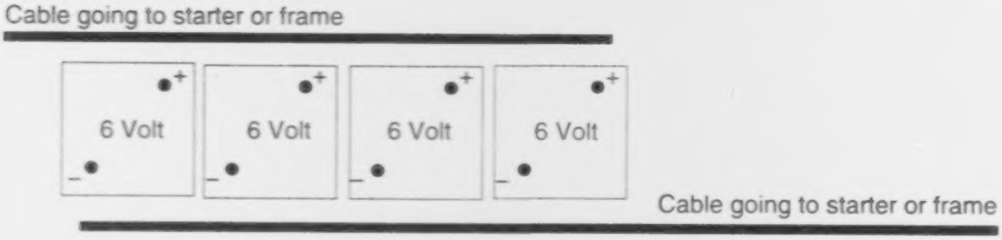

Cable going to starter or frame
+
6 Volt
−
+
6 Volt
−
+
6 Volt
−
+
6 Volt
−
Cable going to starter or frame

Figure 3

b. 12-volt batteries

— 12-volt system

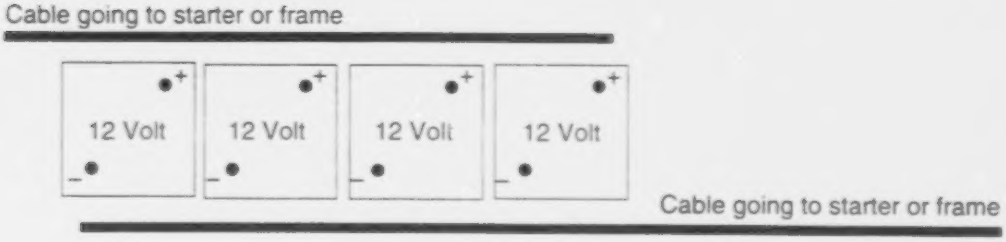
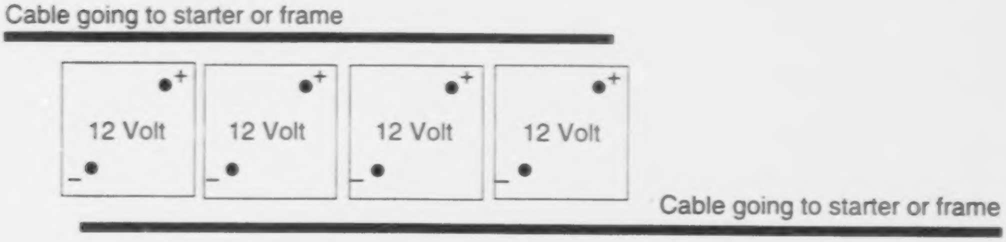

Cable going to starter or frame
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
Cable going to starter or frame

Figure 4

— 24-volt system


Cable going to starter or frame
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
+
12 Volt
–
Cable going to starter or frame

☐ 6. Have your instructor approve your drawings.

☐ 7. Using four batteries or a mock-up of four batteries, connect the batteries in each of the configurations your just diagramed.

☐ 8. Have your instructor check each configuration before attempting to hook-up the next one.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ______
Address ______
Phone # ______
Date In ______
Date Out ______

JOB TICKET

Customer Name ______
Customer Address ______
Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______
Supervisor ______

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Objective 18

Job Sheet 9—Jump-Start a Vehicle

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Prepared vehicle and batteries for procedure properly	______
• Followed correct procedure for connecting jumper cables to batteries	______
• Followed correct procedure for jump start	______
• Followed correct procedure for disconnecting jumper cables from batteries	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

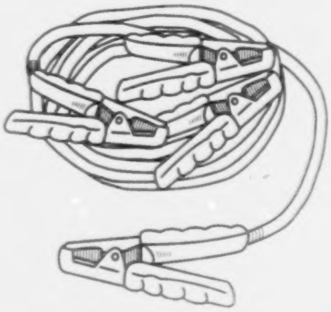
Basic Skills

Reading Science Critical Thinking Employability

Introduction

Jump-starting is a procedure used in an emergency to start a vehicle with a discharged battery. During the procedure, jumper cables, heavy electrical cables with terminal clamps at each end (see Figure 1), are connected between the discharged battery and a good battery, called the booster battery. The booster battery may be a separate battery brought to the vehicle with the discharged battery, or it may be a battery in another vehicle.

Figure 1

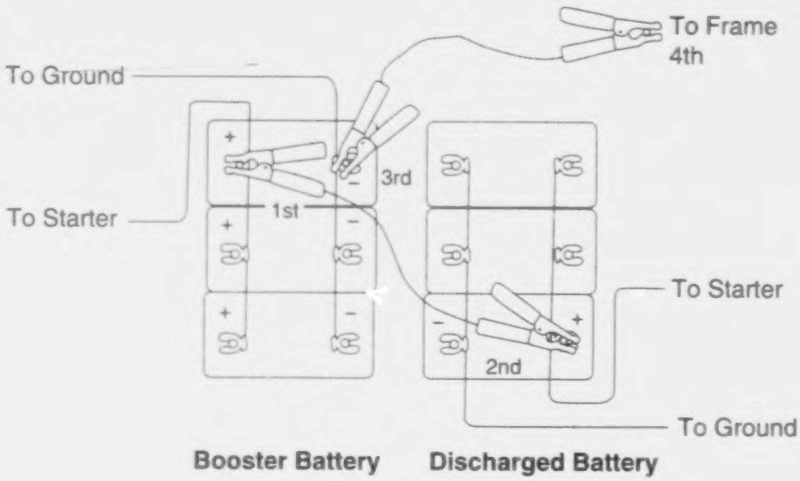


1. Always begin the procedure by connecting one jumper-cable terminal clamp to the positive terminal of the booster battery (identified by a red color, "P", or "+" on the battery case or terminal) and other end of the same cable to the positive terminal of the discharged battery. See Figure 2.

2. Then connect one end of the remaining jumper cable to the negative terminal of the booster battery (identified by a black color, "N", or "–" on the battery case or terminal) and the other end to a good ground—such as the engine block, frame, alternator bracket, or air-conditioner compressor bracket—that is at least 18 inches always from the discharged battery. See Figure 2.

Never connect a booster battery directly to a discharged battery, and never try to ground the cable to any part of the vehicle's fuel system.

Figure 2—Correct method of attaching jumper cables to a 12-volt system



Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Vehicle with a discharged battery
- Appropriate service manual
- Booster battery or auxiliary power supply and instructional manual
- Jumper cables
- Safety glasses
- Rubber gloves
- Rubber apron
- Distilled water

Procedure

Jump-starting a vehicle with a conventional battery

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. If using the booster battery in another vehicle, position vehicles so that they do **not** touch each other.

☐ 6. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 7. Turn off any electrical load in vehicle with discharged battery.

Note: Turn off lights and heater, remove the key from the ignition, and close vehicle doors.

☐ 7. Put on eye protection and protective clothing.

☐ 9. Place fender covers over vehicle fenders.

☐ 10. Prepare discharged battery for jump-starting procedure.

  ☐ a. If ambient (air) temperature is below freezing, check condition of discharged battery's electrolyte.

> **Warning:** At temperatures below freezing, the electrolyte in a discharged battery may freeze. Do not attempt to jump-start a vehicle with a frozen battery. A frozen battery may rupture or explode if jump-start is attempted.

1. Remove battery filler caps.
2. Look down into battery cells, using flashlight beam if necessary in poorly lit area, and determine condition of battery electrolyte.

3. If electrolyte appears to be frozen or if ice crystals are visible in electrolyte, do not attempt jump-start; remove battery from vehicle, and take to a warm environment to allow battery to thaw fully.

4. Proceed with jump-start only if battery is completely thawed.

☐ b. Check electrolyte level.

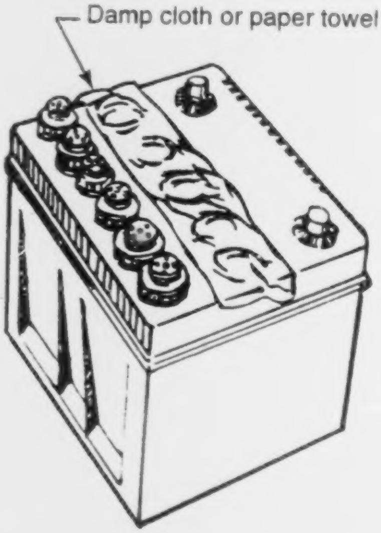
1. Look down into battery cells, using flashlight beam if necessary in poorly lit area, and determine electrolyte level.

2. If electrolyte level is low, fill with water until electrolyte level is above tops of plates.

☐ c. Cover filler holes with damp cloth or paper towel.

Note: Covering the filler holes with a cloth or paper towel will prevent the electrolyte from spewing from the filler holes during the jump-starting procedure.

Figure 3



☐ 11. Connect jumper cables to batteries.

Warning: Connecting the jumper cables in any other than the following sequence can cause a spark that can ignite battery gases and cause the battery to explode.

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☐ a. Connect one jumper-cable terminal clamp to positive terminal of booster battery.

☐ b. Connect terminal clamp at other end of same jumper cable to positive terminal of the discharged battery.

☐ c. Connect one terminal clamp of remaining jumper cable to negative terminal of booster battery.

☐ d. Connect remaining terminal clamp of same cable to a good ground at least 18 inches away from discharged battery.

> **Warning:** Never connect a booster battery directly to the discharged battery. Never ground cable to any part of the vehicle's fuel system.

☐ 12. Place key in ignition of vehicle with discharged battery and attempt to start engine.

> **Warning:** If booster battery is in another vehicle, battery should be disconnected from that vehicle's electrical system. Never leave booster battery connected to electrical system and never start the engine of that vehicle. Extensive damage would result to the electrical system of both vehicles.

☐ 13. Disconnect jumper cables.

Note: Disconnect jumper cables whether or not the vehicle starts on the first try. Further attempts at jump-starting the vehicle will only run down the booster battery.

> **Warning:** Disconnecting the jumper cables in any other than the following sequence can cause a spark that can ignite battery gases and cause the battery to explode.

☐ a. Disconnect jumper-cable terminal clamp from ground on engine.

☐ b. Disconnect jumper-cable terminal clamp from negative terminal of booster battery.

☐ c. Disconnect jumper-cable terminal clamp from positive terminal of discharged battery.

☐ d. Disconnect jumper-cable terminal clamp from positive terminal of booster battery.

☐ 14. Remove damp cloth or paper towel covering filler holes on discharged battery.

☐ 15. Install battery filler caps.

Procedure

Jump-starting a vehicle with a sealed battery

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels.

☐ 4. If using the booster battery in another vehicle, position vehicles so that they do **not** touch each other.

☐ 5. Set parking brake; place vehicle with automatic transmission in PARK and vehicle with manual transmission in NEUTRAL.

☐ 6. Turn off any electrical load in vehicle with discharged battery.

Note: Turn off lights and heater, remove the key from the ignition, and close vehicle doors.

☐ 7. Put on eye protection and protective clothing.

☐ 8. Place fender covers over vehicle fenders.

☐ 9. Prepare discharged battery for jump-starting procedure.

  ☐ a. Determine temperature that battery was exposed to during preceding hours.

  ☐ b. If battery was exposed to subfreezing temperatures and battery appears frozen, do not attempt jump-start; remove battery from vehicle, and take to a warm environment to allow battery to thaw fully.

> **Warning:** At temperatures below freezing, the electrolyte in a discharged battery may freeze. Do not attempt to jump-start a vehicle with a frozen battery. A frozen battery may rupture or explode if jump-start is attempted.

  ☐ c. Check battery state of charge. (Job Sheet 5)

- ☐ d. If hydrometer appears clear or light yellow, do not proceed with jump-starting procedure; replace battery.
- ☐ e. Proceed with jump-start procedure only if the battery is completely thawed.

☐ 10. Connect jumper cables to batteries.

> **Warning:** Connecting the jumper cables in any other than the following sequence can cause a spark that can ignite battery gases and cause the battery to explode.

- ☐ a. Connect one jumper-cable terminal clamp to positive terminal of booster battery.
- ☐ b. Connect terminal clamp at other end of same jumper cable to positive terminal of the discharged battery.
- ☐ c. Connect one terminal clamp of remaining jumper cable to negative terminal of booster battery.
- ☐ d. Connect remaining terminal clamp of same cable to a good ground at least 18 inches away from discharged battery.

> **Warning:** Never connect a booster battery directly to the discharged battery. Never ground cable to any part of the vehicle's fuel system.

☐ 11. Place key in ignition of vehicle with discharged battery and attempt to start engine.

> **Warning:** If booster battery is in another vehicle, battery should be disconnected from that vehicle's electrical system. Never leave booster battery connected to electrical system and never start the engine of that vehicle. Extensive damage would result to the electrical system of both vehicles.

☐ 12. Disconnect jumper cables.

Note: Disconnect jumper cables whether or not the vehicle starts on the first try. Further attempts at jump-starting the vehicle will only run down the booster battery.

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Warning: Disconnecting the jumper cables in any other than the following sequence can cause a spark that can ignite battery gases and cause the battery to explode.

- ☐ a. Disconnect jumper-cable terminal clamp from ground engine.
- ☐ b. Disconnect jumper-cable terminal clamp from negative terminal of booster battery.
- ☐ c. Disconnect jumper-cable terminal clamp from positive terminal of discharged battery.
- ☐ d. Disconnect jumper-cable terminal clamp from positive terminal of booster battery.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Unit 6

Starting Systems Diagnosis & Repair

Unit Contents

Student Components

Student Page

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Information Sheet 6–5

Student Supplement

1—Starting System Diagnosis Chart 6–15

Assignment Sheet

1—Diagnose Starting System Problems 6–17

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1—Make a No-Load Starter Current Draw Test 6–23
2—Make Starter Circuit Voltage Drop Tests 6–27
3—Inspect, Test, and Repair or Replace Switches, Connectors, and Wires of Starter Control Circuits 6–31
4—Inspect, Test, and Replace Starter Relays and Solenoids 6–35
5—Remove and Replace Starter 6–39

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify the parts of a starting system and motor, identify the types of starter field circuits and electromagnetic or lever shift drives, describe the steps in a starting system operation, diagnose starting system problems, make starter circuit tests, and remove and replace a starter. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match the terms related to starting systems diagnosis and repair to their definitions.
2. Select from a list, types of starting aids.
3. Match the terms related to the parts of a starting system to their definitions.
4. Select the major parts of a starting motor.
5. Match the terms related to the component parts of a starting system to their definitions.
6. Arrange the steps in a starting system in the order in which they occur.
7. Complete a statement concerning the conversion of electrical energy into mechanical energy.
8. Select true statements concerning how a starting motor is kept running.
9. Identify four types of starter field circuits.
10. Match types of starter field circuits with the current flow in each type circuit.
11. List four types of starting motor switches.
12. Explain two ways starter drives are engaged.
13. Identify three types of electromagnetic or lever shift drives.
14. Arrange the steps in the operation of a series-parallel switch in the order in which they occur.
15. Arrange the steps in the operation of a transformer-rectifier unit in the order in which they occur.
16. Match starting system tests with their correct descriptions.

17. Describe how types of starting system test equipment are connected to a vehicle.

18. Diagnose starting system problems. (Assignment Sheet 1)

19. Make a no-load starter current draw test. (Job Sheet 1)

20. Make starter circuit voltage drop tests. (Job Sheet 2)

21. Inspect, test, and repair or replace switches, connectors, and wires of starter control circuits. (Job Sheet 3)

22. Inspect, test, and replace starter relays and solenoids. (Job Sheet 4)

23. Remove and replace starter. (Job Sheet 5)

Information Sheet

Objective 1

Terms and definitions

a. **Armature**—Main drive of starter motor; converts electrical energy into mechanical energy

b. **Brushes**—Sliding contacts to feed electrical energy from battery to commutator

c. **Cemf**—Counter electromotive force

d. **Commutator**—Metal segments attached to ends of wire loops to form contact surface or armature

e. **Field winding**—Wire wrapped around pole pieces to increase strength of magnetic field when current is passed through windings

f. **Inertia**—Tendency of a body in motion to remain in motion

g. **Motor switch**—Any switch that closes the circuit between the battery and starter motor

h. **Pinion**—Small gear that meshes with a larger gear

i. **Pole pieces**—Ends of a magnet in the field frame assembly of a starting motor

j. **Solenoid**—Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

k. **Starter switch**—Activates the motor switch

Note: This switch may be either a key or push button

Objective 2

Types of starting aids

Note: Aids may be used singly or in combination.

a. Glow plugs/intake heater

b. Starting fluid

c. Block heater (can be electrical or diesel-fired)

d. Oil heater

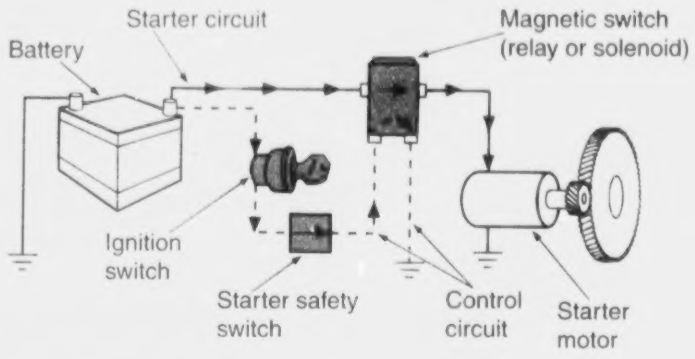
e. Fuel heater

Information Sheet

Objective 3

Parts of a starting system and descriptions of their functions

Figure 1



Note: There are two main classifications of starter systems, *moveable pole shoe* and *solenoid type*. Most vehicles use the solenoid type of starter motor.

a. **Battery**—stores and provides energy to the starting system

Note: The battery supplies the starter motor with heavy current while it supplies the ignition switch with light current.

b. **Cable and wiring**—carry current to the components of the starting system

c. **Ignition switch (key switch)**—controls starting system operation by closing or opening the circuit to the starter relay or solenoid

d. **Starter relay or solenoid**—allows current to flow from the battery through the solenoid to the starting motor

e. **Starter motor**—converts electrical energy coming from the battery into mechanical energy

Note: The starter uses a high torque electric motor capable of turning the gear on the engine flywheel

f. **Starter safety switch**—prevents the engine from cranking unless the shift selector is in neutral or park on an automatic transmission or if the clutch is depressed on a manual transmission

> Warning: Always start the vehicle from inside the vehicle with one foot on the brake. Never try to start the vehicle from outside the driver's seat.

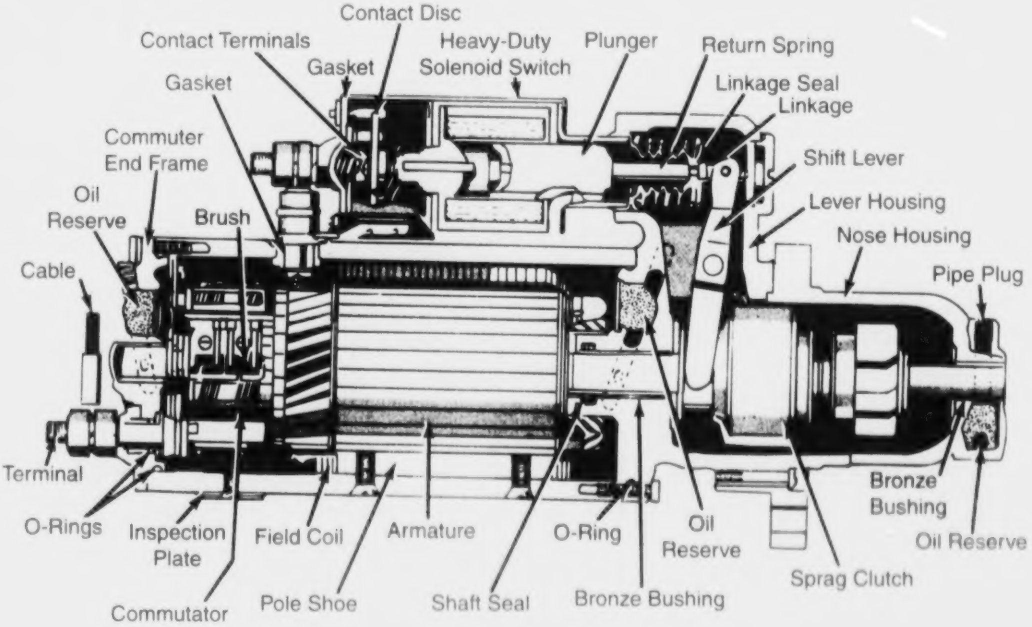
Note: Injury might result if the engine were to crank while in gear. The starting safety switch is usually located on the shift lever mechanism or on the transmission.

Note: Some vehicles also have a brake safety switch that prevents the engine from cranking unless the brake pedal is depressed. Some have a seat belt safety switch that prevents the engine from cranking unless the seatbelt is fastened.

Objective 4

Major parts of a starting motor

Figure 2—Major and secondary parts of a starting motor


Contact Disc
Contact Terminals
Gasket
Heavy-Duty Solenoid Switch
Plunger
Return Spring
Gasket
Linkage Seal
Linkage
Commuter End Frame
Shift Lever
Oil Reserve
Brush
Lever Housing
Nose Housing
Cable
Pipe Plug
Terminal
Bronze Bushing
O-Rings
Inspection Plate
Field Coil
Armature
O-Ring
Oil Reserve
Oil Reserve
Sprag Clutch
Commutator
Pole Shoe
Shaft Seal
Bronze Bushing

a. Motor switch

b. Field frame assembly

c. Armature

d. Drive mechanism

Objective 5

Component parts and descriptions of their functions

a. **Pole shoe**—Forms a magnetic field of force around armature

b. **Field winding**—Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding

c. **Armature**—Converts electrical energy into mechanical energy to drive mechanism to crank engine

Note: The magnetic field around the loop and the field between the pole shoes repel each other causing the loop or armature to turn.

d. **Commutator**—Forms contact surface for battery to feed electrical current through armature

e. **Brushes**—Sliding contacts which feed electrical energy to the commutator

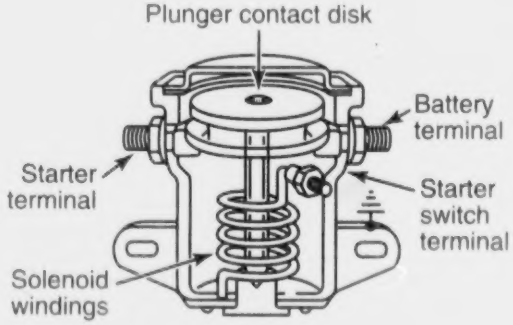
Objective 6

Steps in a starting system operation

1. Current passes from the battery, through the ignition switch, through any safety switches in the system, and finally to the starter relay.

2. The starter relay closes the solenoid contacts allowing current to flow from the battery cables through the solenoid to the starter.

Figure 3



Used with permission of DaimlerChrysler Corp.

3. The current travels through the field coils, brushes, and commutator of the armature of the starter motor creating a magnetic field which causes the armature shaft to spin.

4. The spinning armature shaft of the starter motor is moved forward when the solenoid causes the fork to pivot forward. The spinning pinion drive gear then moves the flywheel by contacting the ring gear portion of the flywheel.

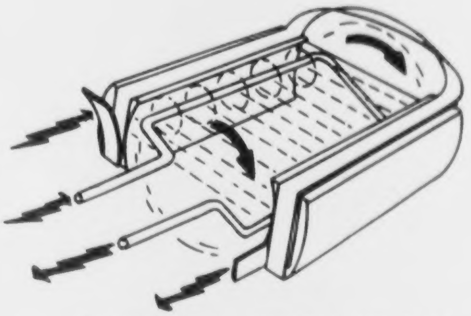
5. When the spinning pinion drive gear contacts the ring gear of the flywheel, the flywheel starts to turn. As the flywheel turns, it spins the crankshaft fast enough to build compression heat to ignite the injected fuel entering the cylinders and start the engine.

Objective 7

Conversion of electrical energy into mechanical energy

Current carrying conductor (armature) formed in a loop and mounted on a shaft, will cause the shaft to rotate when placed inside a magnetic field (field windings).

Figure 4



Loop of Wire Placed in Field Between Poles

Objective 8

How a starting motor is kept running

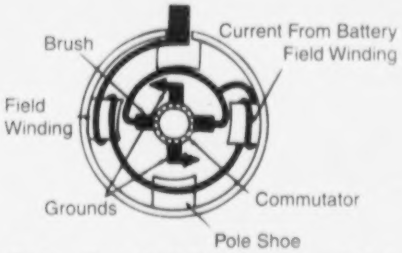
a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

b. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (brushes) which causes the current to flow in the opposite direction in the armature windings.

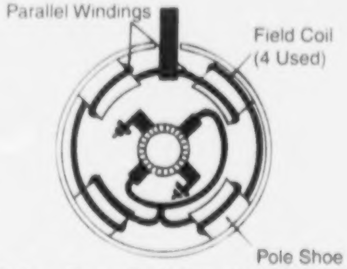
Objective 9

Types of starter field circuits

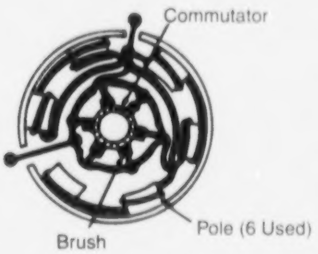
Figure 5


Brush
Current From Battery
Field Winding
Field Winding
Grounds
Commutator
Pole Shoe

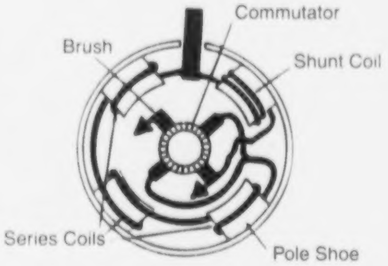
Four-Pole—Two-Coil Series-Wound Motor


Parallel Windings
Field Coil (4 Used)
Pole Shoe

Four-Pole—Four-Coil Parallel-Wound Motor


Commutator
Brush
Pole (6 Used)

Six-Pole—Six-Coil Series-Parallel-Wound Motor


Commutator
Brush
Shunt Coil
Series Coils
Pole Shoe

Compound-Wound Motor

Objective 10

Types of starter field circuits and current flow

a. **Series-wound**—Current flows through all the field windings before it flows through the two insulated brushes to the armature

b. **Parallel-wound**—Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.

c. **Series-parallel-wound**—One third of the current flows through each pair of field windings to one of the three insulated brushes.

d. **Compound-wound**—One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.

Note: The shunt coil is not affected by the counter voltage (CEMF) induced into the armature windings when passing through the magnetic field of the coils.

Objective 11

Types of starting motor switches

a. Manual

b. Solenoid

Note: Solenoid provides a mechanical means for engaging the pinion with the flywheel.

c. Magnetic

Note: Magnetic switch does not provide mechanical shifting.

d. Series-parallel

Objective 12

Engaging starter drives

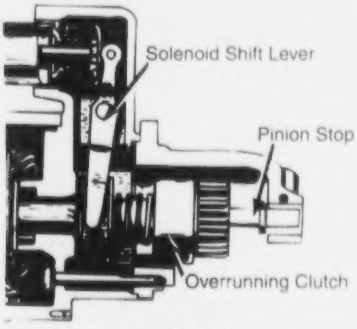
a. Inertia or armature acting through drive mechanism

b. Electromagnetic plunger to mechanically shift pinion into mesh

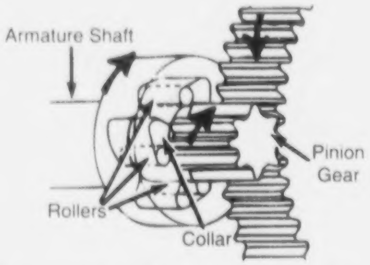
Objective 13

Types of electromagnetic or lever shift drives

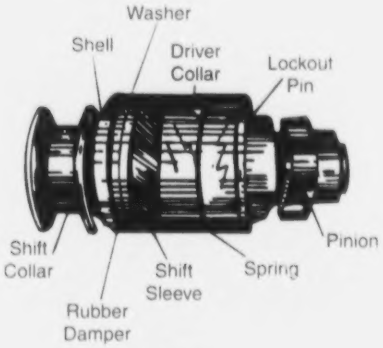
Figure 6


Solenoid Shift Lever
Pinion Stop
Overrunning Clutch

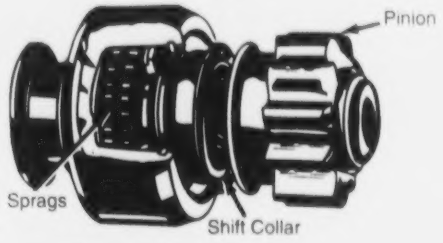
Overrunning Clutch


Armature Shaft
Pinion Gear
Rollers
Collar

Overrunning Clutch Drive Engaged


Washer
Shell
Driver Collar
Lockout Pin
Shift Collar
Rubber Damper
Shift Sleeve
Spring
Pinion

Positork Drive


Pinion
Sprags
Shift Collar

Sprag Clutch Drive

Information Sheet

Objective 14

Operation of a series-parallel switch

a. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.

b. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over.

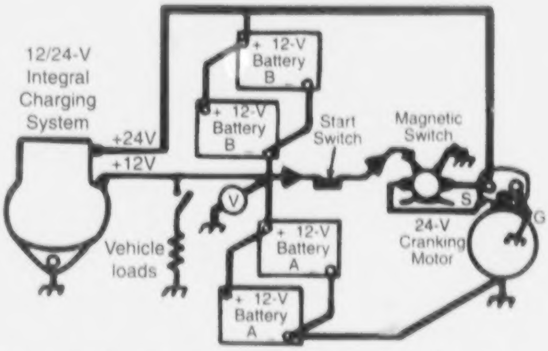
c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation.

Objective 15

Operation of a transformer-rectifier unit

a. The operator closes the start switch, forcing 12 V from the batteries marked "A" through the magnetic switch, closing the cranking motor actuating circuit.f

Figure 7


12/24-V Integral Charging System
+24V
+12V
+ 12-V Battery B
+ 12-V Battery B
Start Switch
Magnetic Switch
S
G
V
Vehicle loads
+ 12-V Battery A
+ 12-V Battery A
24-V Cranking Motor

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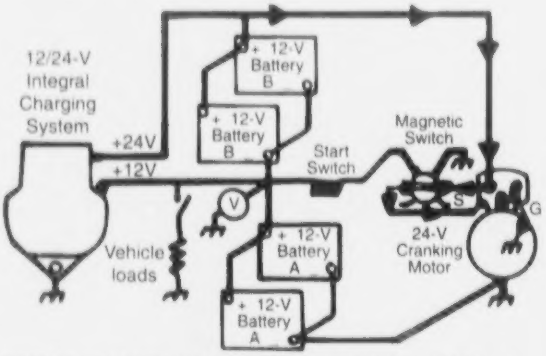
b. The current for the solenoid switch and for cranking flows from the positive posts of the "B" batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.

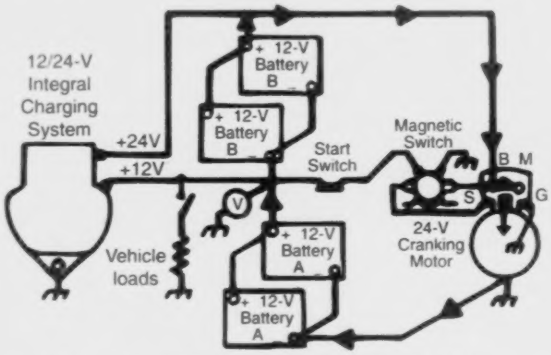
Figure 8


12/24-V Integral Charging System
+24V
+12V
+ 12-V Battery B
+ 12-V Battery B
Start Switch
Magnetic Switch
S
G
V
Vehicle loads
+ 12-V Battery A
+ 12-V Battery A
24-V Cranking Motor

Reprinted with permission of Delco Remy Division, GM Corp.

c. This action energizes the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative part of the batteries marked "A." This action connects both sets of batteries in series, creating 24 V for starting.

Figure 9


12/24-V Integral Charging System
+24V
+12V
+ 12-V Battery B _
+ 12-V Battery B _
Start Switch
Magnetic Switch
B
M
S
G
V
+ 12-V Battery A
+ 12-V Battery A
Vehicle loads
24-V Cranking Motor

Reprinted with permission of Delco Remy Division, GM Corp.

Objective 16

Starting system tests

Name of Test	Condition Evaluated	Components Tested
3-minute battery test	measures the amount of voltage available from the battery	Battery
cranking voltage test	measures the amount of voltage available from the battery for ignition while the engine is being cranked	Battery
current draw test	measures battery voltage and current flow out of the battery	Battery, Starter Motor
starting headlights test	quickly diagnoses a weak or dead battery or a short in the electrical system	Battery, Starter Motor, Cables and Wiring, Ignition Switch, Starting Safety Switch
state-of-charge test	checks the voltage level of the battery charge in batteries that do not have a charge indicator	Battery
voltage drop test	locates higher than normal resistance across a cable, component, or connection during current flow	Cables and Wiring, Ignition Switch, Starter Solenoid or Relay, Starting Safety Switch

Objective 17

Starting system test equipment and their connections

a. **12-volt test light**—The probe should be placed on the switch output wire connection while testing switches, or refer to wiring diagram for test points on relay/solenoid or other components.

b. **Ammeter**—The probe is placed in the test circuit in series between the power source and the load.

c. **Hydrometer**—The rubber tube or stick end of the hydrometer is placed into the electrolyte fluid inside the battery.

Note: Do not use a hydrometer on a sealed battery.

d. **Inductive amp tester**—The clamp is usually clamped around the positive battery cable with the arrow pointing away from the battery.

Note: Many inductive amp testers, also called voltage amperage testers, are available from a variety of manufacturers. Always refer to the manufacturers owners manual for proper instructions.

e. **Load tester**—The leads are connected to the positive and negative battery terminals.

Note: Always use the equipment operating manual for proper connection of leads.

f. **Ohmmeter**—The probe is placed on either side of the wire or component being tested.

Note: Always disconnect the wire or component being tested from its source of electricity.

g. **Voltmeter**—The probe is placed in the test circuit on either side of the load being tested.

Note: Always refer to manufacturer's instructions when connecting test equipment to vehicle.

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Student Supplement 1—Starting System Diagnosis Chart

The most probable causes are listed first.

CONDITION	POSSIBLE CAUSES	CORRECTIVE ACTIONS
Engine cranks slowly, doesn't start	Discharged battery	Charge; test and replace if necessary.
	Very low temperature	Allow battery to warm up, check circuits and battery.
	Battery cables too small	Install correct battery cables.
	Defective starter motor	Test; repair or replace as needed.
	Engine malfunction	Check engine for low oil, mechanical problems.
Solenoid clicks, chatters	Loose or corroded battery terminals	Remove, clean, reinstall.
	Battery discharged	Charge; test and replace if necessary.
	Wiring problem inside solenoid	Replace solenoid.
Lights stay bright vehicle doesn't crank	Open circuit in starter	Disassemble and repair or replace starter.
	Open circuit or high resistance in circuit	Check solenoid and relays; repair or replace if needed.
	Open circuit in safety switch	Check; repair or replace switch.
Lights dim greatly, vehicle doesn't crank	Discharged or malfunctioning battery	Charge and test battery; replace if necessary.
	High resistance at battery connection	Clean and tighten terminal connections
	Loose or corroded battery terminals	Remove, clean, reinstall.
	Very low temperature	Allow battery to warm up; check circuits and battery.
	Pinion not engaging ring gear	Check for damaged parts, alignment of starter.
	Solenoid engaged by not cranking	Check starter motor and connections.
	Pinion jammed—starter and flywheel out of alignment	Check pinion and gear teeth.
	Stuck armature in starter	Replace or repair starter.
	Short in starter	Replace or repair starter.
	Engine malfunction	Check engine for low oil, mechanical problem.
	High resistance in starter	Disassemble and repair or replace starter.

Student Supplement 1

CONDITION	POSSIBLE CAUSES	CORRECTIVE ACTIONS
Lights out, vehicle doesn't crank	Poor connection (probably at battery or ground)	Clean cable clamp and terminal; tighten clamp.
	Open circuit	Clean and tighten connections, replace wiring if necessary.
	Discharged or malfunctioning battery	Charge and test battery; replace if necessary.
Whine or siren sound just after starting	Overrunning clutch defective	Repair or replace as needed.
	Solenoid plunger sticking	Repair or replace solenoid.
	Weak return spring	Replace spring.
	Damaged flywheel ring gear teeth	Remove and replace.
	Pinion jammed, too tight—starter and flywheel out of alignment	Check pinion alignment with gear teeth; shim if necessary.
Starter turns, engine does not	Pinion not engaging—starter and flywheel out of alignment	Check pinion alignment with gear teeth; shim if necessary
	Pinion slipping	Replace or repair starter.
	Damaged flywheel ring gear teeth	Remove and replace.
Pinion disengages slowly when engine starts	Solenoid plunger sticking	Repair or replace solenoid.
	Overrunning clutch defective	Repair or replace as needed.
	Weak return spring	Replace spring.
	Pinion jammed, too tight—starter and flywheel out of alignment	Check pinion alignment with gear teeth; shim if necessary.

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Objective 18

Assignment Sheet 1—Diagnose Starter System Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 10 of the 12 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading

Critical Thinking

Introduction

Common starting system problems start with a no or slow crank problem. However, not all no and slow crank problems are due to a faulty electrical problem in the starting system. It is important for the technician to differentiate between electrical and engine mechanical problems that can cause a no or slow crank problem. Visual inspection of the engine is very important when determining the cause of the problem.

A weak or dead battery, corroded battery cable connections, and/or damaged or worn components of the starting system may all cause a no crank or slow crank problem. Since a dead or weak battery is the most common source of a faulty starting system, the first test a technician should do is to visually inspect the battery for signs of corrosion, wear, or low fluid level. When diagnosing starting system problems, always check the battery first. The conditions to check are:

- electrolyte level in the battery
- loose or corroded battery terminal connections
- dirt buildup on the battery top
- battery hold-down connections, clamps, and tray
- cracks and other physical damage on the battery case and terminals

If any of those conditions are present, follow the manufacturer's advice to correct the problems.

Warning: Wear eye protection when working around batteries. Batteries contain acid that could cause blindness. Even the film buildup on a battery can contain acid.

Assignment Sheet 1

After inspecting the battery, a visual inspection of the engine can help identify a mechanical problem as well. Common mechanical problems are:

- belt wear or damage
- belt-driven part damage
- engine block damage
- low or no engine oil level
- oil pan damage
- seized engine
- transmission clutch failure

If starting problems still exist after checking and correcting problems with the battery, and if there is no visual sign of battery damage or mechanical damage, try to pinpoint the cause by doing a starting headlight test. The steps to follow are:

1. Turn the headlights on.
2. Start, or attempt to start, the engine.
3. Observe the change in the headlights while the starter is cranking.
4. Refer to the "Starting System Diagnosis Chart" to determine probable cause.
5. Determine if additional tests are needed.
6. Perform tests.
7. Determine needed repairs or replacements.

If the headlights test indicates a weak or dead battery, then you should perform a battery load test, state of charge test, or cranking voltage test. If the headlights test indicates a short, heavy current draw, or high resistance in the starting circuit, then a starter current draw test and/or circuit voltage drop test may be required before further diagnosis can be made.

If all the tests indicate that the problem is not due to a faulty starting system, the technician should look for mechanical failure as a probable cause of cranking failure. Refer to Student Supplement 1, "Starting System Diagnosis Chart" and the service manual for specific conditions which indicate mechanical failure.

Be sure and follow all general safety rules for dealing with batteries. Refer to the vehicle service manual for specific instructions on starting system procedures.

Assignment Sheet 1

Directions

Use Student Supplement 1, Starting System Diagnosis Chart and the information in the introduction to answer the following questions. Circle the correct answer or fill in the answer on the blanks provided.

1. Name three common sources that may cause a no crank or slow crank problem.

2. Name three tests that should be performed if the headlights test indicates a weak or dead battery.

3. Name two tests that should be performed if the headlights test indicates a short, heavy current draw, or high resistance in the starting circuit.

4. Name four conditions to check when checking the battery.

5. Technician A has performed a starting headlight test and has observed the headlights dim greatly but the vehicle doesn't crank. Which of the following mechanical problems is most likely to cause this condition?

   a. engine block damage
   b. short in the starter motor
   c. low oil
   d. very low temperature of battery

Assignment Sheet 1

6. Name three mechanical problems that can be identified by visual inspection of the engine that might cause a no or slow crank problem.

7. Name three electrical starter system problems that can be identified by visual inspection of the engine that might cause a no or slow crank problem.

8. A clicking and clattering noise is heard when trying to start the engine of a vehicle with a no crank problem. Technician A says the transmission clutch has failed. Technician B says a defective solenoid is probably the problem. Which technician is correct?

   a. Technician A
   b. Technician B
   c. Both Technician A and B
   d. either Technician A nor B

9. After checking the engine oil level on a vehicle with a no crank complaint, Technician A finds a low level. Technician A fills it with oil and tries to crank the engine again. The engine cranks slowly but doesn't start. Technician A says it is a mechanical problem. Technician B says more testing is needed. Which technician is correct?

   a. Technician A
   b. Technician B
   c. Both Technician A and B
   d. either Technician A nor B

10. A wiring problem is found inside the solenoid. What action should be taken to correct the problem?

    a. Test and replace wires
    b. Replace solenoid
    c. Check engine for mechanical problems
    d. None of the above

11. A driver complains that occasionally the vehicle won't start; when the engine starts it has a whine or siren sound just after starting. Technician A says the starter motor gear is slipping. Technician B says that the flywheel is damaged. Who is correct?

    a. Technician A
    b. Technician B
    c. Both Technician A and B
    d. either Technician A nor B

12. A vehicle owner complains that the engine will not crank. Technician A says the problem is mechanical. Technician B says that the battery should be tested before looking for mechanical problems. Who is correct?

    a. Technician A
    b. Technician B
    c. Both Technician A and B
    d. either Technician A nor B

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Objective 19

Job Sheet 1—Make a No-Load Starter Current Draw Test (Off Vehicle)

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manul is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

A no-load starter current draw test measures battery voltage and current flow out of the battery, and should be conducted when a starter motor problem has been indicated. The no-load test can identify open or shorted fields, and specific defects in the starter. The starter current draw test can also be used to test a rebuilt starter before placing it on the vehicle.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Other equipment and supplies as required by procedure
- Safety glasses
- Voltmeter
- Ammeter
- Carbon pile
- RPM indicator

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

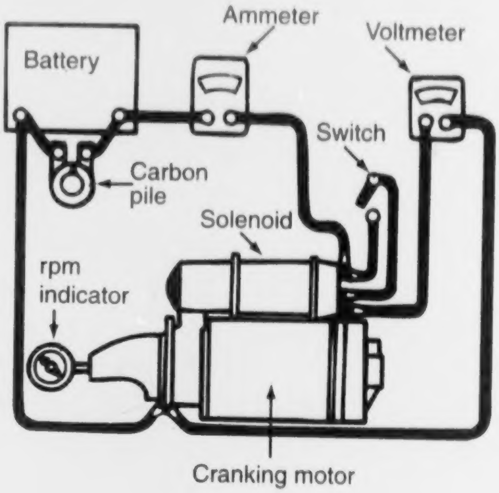
☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Secure the starter in a bench vice.

☐ 6. Connect the test equipment as shown in figure 1.

Figure 1



☐ 7. Connect a voltmeter from the motor terminal to the motor frame.

☐ 8. Connect a carbon pile across the battery and set to the desired voltage.

Note: An RPM gauge can be used to determine the RPM of the starter.

☐ 9. Connect an ammeter in series with a battery and a switch (in the open position), from the solenoid battery terminal to the solenoid switch terminal.

☐ 10. After closing the switch, compare the rpm, current, and voltage readings with the service manual or manufacturer's specifications.

Note: If the cranking voltage and cranking amps are within manufacturer's specifications, then the system is good.

☐ 11. If readings are not within specifications, then there is a problem with current flow out of the battery and further inspections are required.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

992

993

Objective 20

Job Sheet 2—Make Starter Circuit Voltage Drop Tests

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manul is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Interpersonal Employability

Introduction

A voltage drop test will locate higher than normal resistance across a cable, component, or connection during current flow. It is performed when the headlight test indicates a problem in the starting system. Wires or components do not need to be disconnected to check for internal voltage drops. Connecting the voltmeter leads and testing at various connections within the starting system and on its components will determine where the problem is located. The voltage drop should not exceed 0.1 volts, an excessive voltage drop indicates a high resistance between the voltmeter leads—the problem is located between the voltmeter leads.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Clock, watch, or timer
- Digital multimeter or DVOM
- Technician's common hand tools
- Appropriate servcie manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by procedure

Note: You will need the help of an assistant for this Job Sheet.

Note: Preference should be given to the Technology and Maintenance Council (TMC) procedures if available. TMC procedures don't normally include cranking the engine/starter as part of the testing procedure. This prolongs the life of the starter.

Job Sheet 2

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Crank the engine.

☐ 6. If the engine cranks slowly or does not crank at all, touch the positive voltmeter probe to the positive battery terminal and the negative voltmeter probe to the positive terminal at the starter.

☐ 7. Have your assistant crank the engine while you look at the reading on the voltmeter; it should show zero. If the voltage drop (the difference between voltage shown BEFORE cranking and WHILE cranking) is more than .5 V, there is a problem in the circuit between the battery's positive terminal and the starter.

Note: A typical voltage drop should not exceed 0.1 volts across a wire or cable and 0.1 volts across the switch.

> Warning: Cranking the starter for more than 10 to 30 seconds without allowing it to cool down for at least a minute will damage the starter. DO NOT CRANK THE STARTER LONGER THAN THE TIME THE MANUFACTURER RECOMMENDS. Refer to the manufacturer's service manual for maximum cranking times and minimum cool down times.

☐ 8. If there is a voltage drop, check for the voltage drop across each component of the circuit by leaving the positive probe of the voltmeter on the positive terminal of the battery and moving the negative probe of the voltmeter to the connection of each system component, in turn, checking the voltage drop as in Step 7.

Note: When the voltage drop lessens, the last component tested is the problem.

☐ 9. If there is no significant voltage drop on the positive side of the circuit, check the negative side by touching the positive voltmeter probe to the starter frame and the negative voltmeter probe to the negative terminal of the battery.

☐ 10. Have your assistant crank the engine as in Step 7; if the voltage drop is more than 0.1 there is a problem in the circuit between the battery's negative terminal and the starter.

☐ 11. If this is the case, check for the voltage drop across each component of the circuit by leaving the negative voltmeter probe in contact with the negative battery terminal and moving the positive voltmeter probe to the connection of each system component, in turn, checking the voltage drop as in Step 8.

Note: When the voltage drop lessens, the last component tested is the problem.

☐ 12. Clean and tighten the connections of any component that tests bad and retest as in Step 8; if the problem still exists, the component must be replaced.

☐ 13. If there is no voltage drop in any part of the circuit, and the starter still doesn't crank well, you must test and possibly replace the starter.

☐ 14. Start your engine and verify repair.

☐ 15. Turn in job ticket when finished.

☐ 16. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________

Address ____________

Phone # ____________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________

Customer Address ____________

Customer Phone # ____________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested ____________

Services/repairs made: ____________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________ Date ____________

Technician ____________

Supervisor ____________

Objective 21

Job Sheet 3—Inspect, Test, and Repair or Replace Switches, Connectors, and Wires of Starter Control Circuits

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manul is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

Visually inspecting switches, connectors, and wires of starter control circuits for tightness, wear, and damage is a common practice when diagnosing starting system problems. A battery cable problem can cause a battery to appear weak or dead when it is not. If the cables, connectors, and wires do not allow enough current flow, the starter may not turn or may turn slowly.

Bad switches may also keep a starter system from working properly. A voltmeter or a test light may be used to test switches, connectors, and wires. A voltage drop test is used to test cables and wiring along the starter system path. A test light is used to test the ignition switch and the safety switches. By touching a test light to the starter solenoid terminal, the technician can determine if the ignition switch is good. The test light will glow when the key is turned to start the engine. If the test light does not glow, either a wire in the ignition switch is shorted or the ignition switch is defective. When testing the starting safety switch, touch the test light to the switch output wire connection while moving the transmission shift lever. When the shift lever is moved into park or neutral, the light will glow if the switch is good. The test light should not glow when the shift lever is moved in any other position.

When repair or replacing switches, connectors, and wires always refer to the appropriate service manual for exact procedure.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 3

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate servcie manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by procedure

Note: Preference should be given to the Technology and Maintenance Council (TMC) procedures if available. TMC procedures don't normally include cranking the engine/starter as part of the testing procedure. This prolongs the life of the starter.

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 3

Objective 22

Job Sheet 4—Inspect, Test, and Replace Starter Relays and Solenoids

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manul is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

Inspecting and testing a starter relay and solenoid is indicated when there is a click with no cranking, no cranking with no click, slow cranking, no cranking, or if the starter motor won't shut off. The contacts of the solenoid may be damaged and therefore causing a high resistance problem that blocks the current from the battery to the starter. Use a voltmeter to measure the voltage drop and resistance of the solenoid lugs and contacts. If a voltage drop test indicates that the solenoid should be replaced, follow manufacturer's instructions for the procedure.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Clock, timer, or watch
- Digital multimeter or voltmeter
- Technician's common hand tools
- Appropriate servcie manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disable the fuel system.

☐ 6. Check the starter relay (if present) and the solenoid for burned terminals or severely corroded or loose connections.

Note: Burned or corroded terminals normally, but not always, indicate a component which is damaged and must be replaced.

☐ 7. If you find these problems, test the affected areas.

☐ 8. Check for loose connections or melted fusible links in the circuit between the battery and the starter and between the starter and the vehicle body.

☐ 9. Tighten all loose connections and replace any melted fusible links.

☐ 10. Reconnect the coil wire and try to crank the engine.

☐ 11. If the engine cranked slowly or not at all in Step 10, stop cranking and touch the positive voltmeter probe to the positive terminal of the battery and the negative voltmeter probe to the positive terminal at the starter. Notice the reading on the voltmeter.

☐ 12. While your assistant cranks the engine, look at the reading on the voltmeter. If the voltage drop (the voltage reading BEFORE cranking minus the voltage reading WHILE cranking) is more than .5 V, there is a problem in the circuit between the battery's positive terminal and the starter.

> Warning: Cranking the starter for more than 10 to 30 seconds without allowing it to cool down for at least a minute will damage the starter. DO NOT CRANK THE STARTER LONGER THAN THE TIME THE MANUFACTURER RECOMMENDS. Refer to the manufacturer's service manual for maximum cranking times and minimum cool down times.

☐ 13. If there is a voltage drop, check for the voltage drop across each component of the circuit by leaving the positive probe of the voltmeter on the positive terminal of the battery and moving the negative probe of the voltmeter to the connection of each system component, in turn, checking the voltage drop as in Step 12.

Note: When the voltage drop lessens, the last component tested is the problem.

☐ 14. If there is no significant voltage drop on the positive side of the circuit, check the negative side by touching the positive voltmeter probe to the starter frame and the negative voltmeter probe to the negative battery terminal.

☐ 15. Have your assistant crank the engine as in Step 12; if the voltage drop is more than .2 V, there is a problem in the circuit between the battery's negative terminal and the starter.

☐ 16. If this is the case, check for the voltage drop across each component of the circuit by leaving the negative voltmeter probe in contact with the negative battery terminal and moving the positive voltmeter probe to the connection of each system component, in turn, checking the voltage drop as in Step 12.

Note: When the voltage drop lessens, the last component tested is the problem.

☐ 17. Clean and tighten the connections of any component that tests bad and retest as in Step 12: if the problem still exists, the component must be replaced.

☐ 18. If there is no voltage drop in any part of the circuit and the starter still doesn't crank well, you must test and possibly replace the starter.

☐ 19. Start engine and verify repair.

☐ 20. Turn in job ticket when finished.

☐ 21. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 4

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

Services/repairs made	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 23

Job Sheet 5—Remove and Replace a Starter

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manul is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Mathematics Science Oral Communication

Introduction

A faulty starter motor can cause slow cranking, no cranking, overheating of starter cables, and abnormal noises while cranking. Before removing the starter motor, inspect it closely for corrosion or loose connections. Check to make sure the bolts and wires are tight. If the problem is found to be a defective starter motor, remove and replace it.

Always follow manufacturer's instructions when removing and replacing the starter motor.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Battery cable pliers
- Safety glasses
- Technician's common hand tools
- Appropriate servcie manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Warning: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Job Sheet 5

Procedure

Remove starter

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

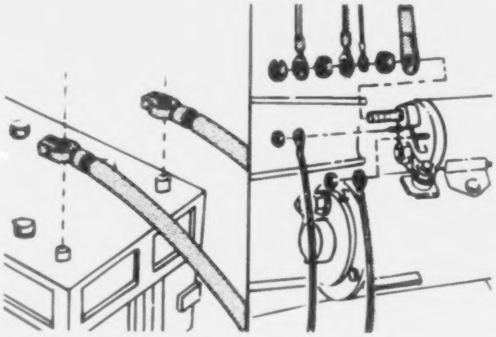
Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disconnect battery ground cable.

☐ 6. Remove the cables and electrical wires from the starter and label (Figure 1).

Note: In some cases it may be necessary to remove the starter retaining bolts and allow the starter to be lowered to provide easy removal of the starter wires and cables.

Figure 1

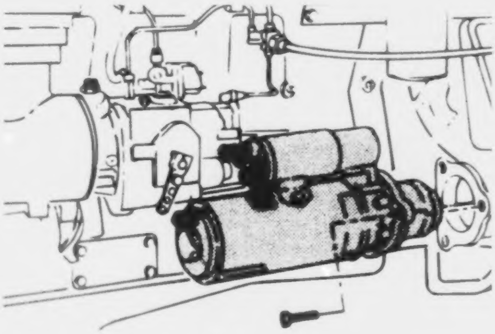


Courtesy of Cummins Engine Co., Inc.

☐ 7. Remove starter retaining bolts as required (Figure 2).

Warning: The starting motor mounting capscrews can be metric or standard thread sizes. Be sure to install the same size capscrews which were removed.

Figure 2



Courtesy of Cummins Engine Co., Inc.

☐ 8. Remove other starter brackets if used.

☐ 9. Remove starter from engine.

> Warning: Starter motors are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.

Replace starter

☐ 1. Clean starter and block mountng surfaces.

☐ 2. Position starter in mounting position and start retaining bolts.

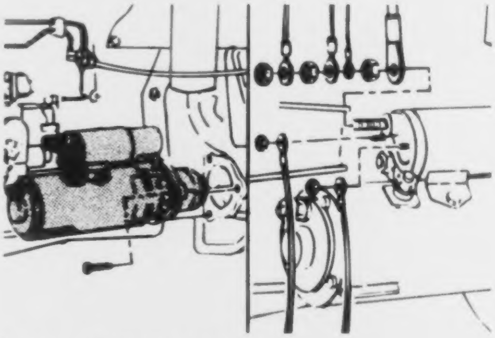
☐ 3. Tighten starter retaining bolts securely.

☐ 4. Position starter wires and cables in place and start retaining nuts.

☐ 5. Tighten starter wires and retaining nuts securely (Figure 3).

Note: Avoid overtightening and twisting off small retaining nuts.

Figure 3



Courtesy of Cummins Engine Co., Inc.

☐ 6. Replace any brackets that may have been removed and tighten securely.

☐ 7. Check all connections.

☐ 8. Replace battery ground cable.

☐ 9. Start engine two or three times to check starter action.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 5

Unit 7 Charging Systems Diagnosis & Repair

Unit Contents

Student Components

Student Page

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Information Sheet 7–5

Student Supplement

1—Charging System Diagnosis Chart 7–11

Assignment Sheet

1—Diagnose Charging System Problems That Cause an Undercharge, a No-Charge, or an Overcharge Condition 7–13

Job Sheets

1—Inspect, Adjust, and Replace Alternator Drive Belts, Pulleys, and Tensioners 7–17
2—Make a Charging System Output Test; Determine Needed Repairs 7–21
3—Make a Charging Circuit Voltage Drop Test; Determine Needed Repairs 7–25
4—Test an S.I. Series Alternator 7–29
5—Inspect, Repair, or Replace Connectors and Wires of Charging Circuits 7–35
6—Remove, Inspect, and Replace an Alternator 7–39

Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose charging system problems that cause an undercharge, no-charge, or overcharge condition, inspect, adjust, and replace alternator drive belts, pulleys, and tensioners, make a charging system output test and a charging circuit voltage drop test, test an S.I. series alternator, inspect, repair, or replace connectors and wires, and remove, inspect, and replace an alternator. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match the terms related to charging systems diagnosis and repair to their definitions.
2. State the purpose of a charging system, an alternator, and charging system output tests.
3. Match alternator charging circuit components with their correct functions.
4. Identify the major parts of an alternator.
5. Describe how stator windings are constructed.
6. Distinguish between types of alternator circuits.
7. Select characteristics of a brushless alternator.
8. Select true statements concerning operation of a brushless alternator.
9. Select true statements concerning operation of a transistorized regulator.
10. Complete statements concerning safety rules for working with alternator charging circuits.
11. Match the names of charging system tests with descriptions of the conditions evaluated by the tests.
12. Describe how charging system test equipment is connected to the vehicle.
13. Diagnose charging system problems that cause an undercharge, a no-charge, or an overcharge condition. (Assignment Sheet 1)
14. Inspect, adjust, and replace alternator drive belts, pulleys, and tensioners. (Job Sheet 1)

Objective Sheet

15. Make a charging system output test; determine needed repairs. (Job Sheet 2)

16. Make a charging circuit voltage drop test; determine needed repairs. (Job Sheet 3)

17. Test an S.I. series alternator. (Job Sheet 4)

18. Inspect, repair, or replace connectors and wires of charging circuits. (Job Sheet 5)

19. Remove, inspect, and replace an alternator. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Brushless alternator**—An alternator that has neither slip rings nor brushes

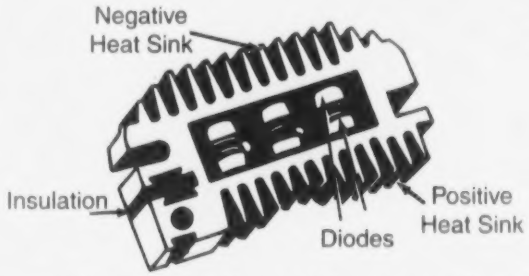
b. **Heat sink**—Dissipates heat from diodes

Note: High ampere alternators often use finned diodes for better heat removal.

c. **Open circuit**—Circuit in which a wire is broken or disconnected

d. **Rectifier bridge**—Six diodes mounted in one assembly

Figure 1



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e. **Rotor**—Wire coil wrapped around an iron core and mounted on a rotating shaft

Note: The rotor assembly does the same job for the alternator as the field coil and pole shoe do for the generator; however, the rotor assembly revolves.

f. **Slip rings**—Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft.

Note: Current flows through the regulator, through the insulated brush, through one slip ring into the coil, and out through the other slip ring and the other brush to ground.

g. **Stator**—Laminated soft iron ring with three groups of coils

Note: The stator assembly does the same job as the armature in a generator; however, the stator is fixed while the armature turns.

h. **Transistorized regulator**—Fully electronic unit composed of resistors, diodes, zener diode, transistors, and thermistor

Information Sheet

Objective 2

Purpose of a charging system, an alternator, and charging system output tests

a. The purpose of the **charging system** is to restore the battery's electrical charge and supply electricity to the electrical accessories.

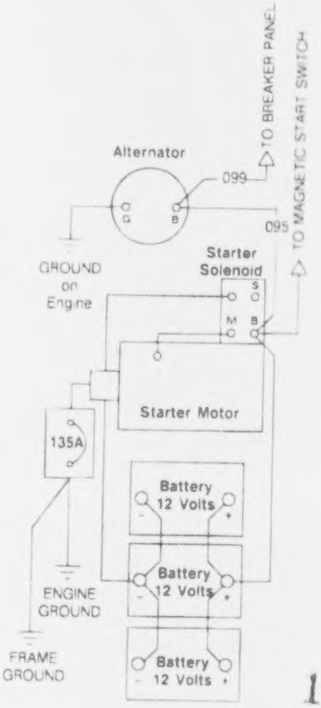
Note: The battery provides enough energy to the starting system to crank the engine but as the battery drains and engine speed increases, the charging system is able to produce more voltage than the battery can deliver to other electrical accessories.

b. The purpose of an **alternator** is to convert mechanical energy from the operation of the engine into the electrical energy required to restore the electrical charge of the battery.

Note: A generator was used as the primary type of charging device in vehicles prior to 1960. Today, an alternator has replaced the generator as the primary type of charging device.

c. The purpose of **charging system** output tests is to measure system current and voltage under maximum load.

Figure 2—Starting/Charging System Schematic


TO BREAKER PANEL
TO MAGNETIC START SWITCH
Alternator
099
G
B
095
GROUND
on
Engine
Starter
Solenoid
S
M
B
Starter Motor
135A
Battery
12 Volts
-
+
Battery
12 Volts
-
+
ENGINE
GROUND
FRAME
GROUND
Battery
12 Volts
-
+

Objective 3

Alternator charging circuit components and functions

a. **Battery**

- Supplies current to crank the engine
- Helps out during peak operation when electrical load is too much for alternator
- Stabilizes system voltage

b. **Alternator**

- Supplies electrical power to accessory circuits
- Recharges battery

c. **Regulator**—Limits the alternator voltage to a safe, preset value

d. **Ammeter**—Measures the rate of current flow

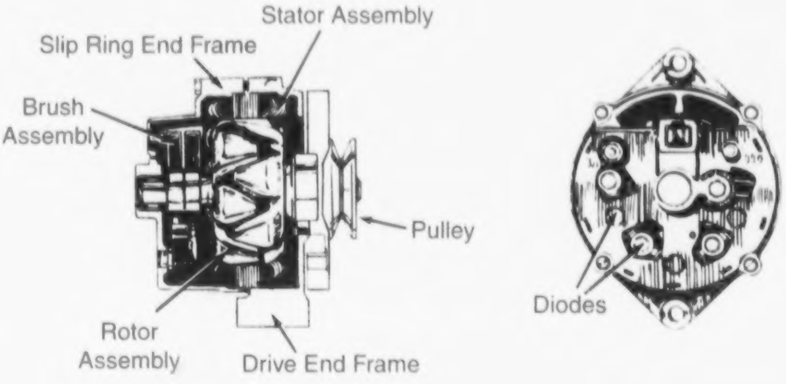
e. **Voltmeter**—Indicates produced voltage

f. **Indicator lights**—Indicates problems in system; used in place of a meter

Objective 4

Major parts of an alternator

Figure 3


Stator Assembly
Slip Ring End Frame
Brush Assembly
Pulley
Rotor Assembly
Drive End Frame
Diodes

Information Sheet

Objective 5

Construction of stator windings

Windings have three phases which are connected together to form a "Y" or delta connection, with each winding connected to a postive and negative diode.

Objective 6

Types of alternator circuits

Note: The regulator places a resistance in the field circuit which reduces current flow to the alternator rotor.

a. **External regulator**—Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a "B" circuit.

b. **Internal regulator**—Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an "A" circuit.

Objective 7

Characteristics of a brushless alternator

a. High mileage unit

b. Used on both gasoline and diesel engines

c. Regulator compartment can be vented for increased capability

d. Uses large bearings at both ends

e. Has extra large grease reservoirs

f. Has extra large lip seal to keep grease in and dirt out

g. Regulator compartment is air tight

h. Designed to operate between engine overhauls without attention

Objective 8

Operation of a brushless alternator

a. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.

b. The field coil is mounted to the end frame.

c. The rotor is mounted on bearings and fits between the stator and field coil.

d. The field coil produces a north pole at the right hand side of the coil.

e. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.

10-0

f. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.

g. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings.

Objective 9

Operation of a transistorized regulator

a. Allows battery current to excite the alternator field coils

b. Controls charging voltage at safe values during operation by regulating the field current

Objective 10

Safety rules for working with alternator charging circuits

a. Never attempt to polarize the circuit.

b. Be sure the battery is in good operating condition before making any tests or adjustments.

c. Never operate the alternator in an open circuit, except when instructed in the technical manual.

d. Never short or ground the alternator terminals.

e. Do not disconnect the voltage regulator while the alternator is running.

f. Disconnect the negative battery cable first when removing the alternator or battery.

g. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder.

h. Never immerse the circuit components in cleaning solution.

Objective 11

Names of charging system tests with descriptions of the conditions evaluated by the tests

Note: Components tested by charging system tests include the battery, charge indicator lamp or gauge, drive belt, alternator, related wiring cables and switches, and the voltage regulator. The starter relay, ignition switch, and fusible links are included in some charging systems. Refer to appropriate vehicle service manual.

a. **Battery high-rate discharge test**—measures the lowest point to which the battery voltage drops while the battery is discharging at a high rate

b. **Circuit voltage drop test**—locates higher than normal resistance across a cable, component, or connection during current flow

c. **Alternator output test**—measures the maximum current the alternator can produce at a specified voltage or maximum load

d. **Regulator bypass test**—measures the current and voltage output of the charging system leaving the regulator out of the circuit

e. **Regulator voltage test**—checks the calibration of the voltage regulator and detects a high or low voltage setting

f. **State-of-charge test**—checks the voltage level of the battery charge in batteries that do not have a charge indicator

Note: When troubleshooting problems with the charging system, there are four common conditions: dead battery, overcharged battery, abnormal noises, or an indicator light or ammeter on the instrument panel shows a problem. Testing the charging system requires testing the battery, alternator, regulator and visually inspecting the components.

Objective 12

Charging system test equipment and their connections

a. **Ammeter**—The probes are placed in the test circuit in series between the power source and the load.

b. **Belt tension gauge**—Clamp the gauge onto the belt and read the gauge to measure the tension placed on the drive belt.

c. **Hydrometer**—The rubber tube or stick end is placed into the electrolyte fluid inside the battery.

Note: Do not use a hydrometer on a sealed battery.

d. **Inductive amp tester**—The clamp is usually clamped around the positive battery cable with the arrow pointing in the direction of current travel.

Note: Many inductive amp testers, also called voltage amperage testers, are available from a variety of manufacturers. Always refer to the manufacturer's owners manual for proper instructions on connections.

e. **Load tester**—The leads are connected to the positive and negative battery terminals. Use the equipment operating manual for directions on connecting other leads.

f. **Ohmmeter**—After the wire or component being tested has been disconnected from a source of voltage, the probes are placed on either side of the wire or component being tested.

g. **Voltmeter** — The probes are placed in the test circuit on either side of the load being tested.

Student Supplement 1—Charging System Diagnosis Chart

The most probable causes are listed first.

CONDITION	POSSIBLE CAUSES	CORRECTIVE ACTIONS
Faulty operation of lighting and electrical options (Undercharge)	Loose wiring connections	Inspect and repair wiring.
	High resistance in circuit	Test circuit, repair alternator.
	Defective regulator	Test and repair or replace alternator.
Low or no voltage (No-charge)	Defective drive belt	Adjust or replace belt.
	Dirty or loose battery cables	Clean, tighten, or replace cables.
	Defective battery	Test and charge or replace.
	Incorrect battery	Replace with correct battery.
	Faulty system wiring	Repair wiring.
	Faulty alternator	Repair or replace.
	Defective regulator	Repair or replace.
High voltage (Overcharge)	Faulty regulator	Replace or adjust regulator.
	Defective battery	Remove and replace.
	Faulty ground at regulator	Repair regulator ground.
	Defective regulator	Repair or replace.

Objective 13

Assignment Sheet 1—Diagnose Charging System Problems That Cause an Undercharge, a No-Charge, or an Overcharge Condition

Name ____________________ Overall Rating ________

Date ____________________

Evaluation Criteria	Rating
• Directions are followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Mathematics Critical Thinking

Introduction

When diagnosing charging system problems, always start with the battery. A weak or dead battery, corroded battery cable connections, and/or damaged or worn components may cause a no crank or slow crank problem . Check for dirt buildup on the battery top, case damage, loose or corroded connections, or any other trouble that could upset battery operation. After checking the battery for problems, quickly pinpoint the cause of the problems by doing a visual inspection of the charging system components. The charging circuit may have shorted electrical wires or loose connections. If no problems are found, a charging system output test, a voltage regulator bypass test, and/or a circuit resistance test may be required, depending upon the condition observed.

Directions

Review and use Student Supplement 1, *Charging System Diagnosis Chart*, to answer the following questions. Write your answer in the blank provided.

____ 1. What is the most likely cause of an overcharged system?

a. High resistance in the alternator
b. Open voltage regulator
c. Defective battery
d. Defective alternator

____ 2. If the condition of the charging system has been reported as low or no charge, which of the following is a possible cause?

a. Defective battery
b. Defective alternator
c. Loose battery cables
d. All of the above are possible causes

____ 3. How would you correct the problem of a defective alternator?

a. Replace alternator
b. Replace voltage regulator
c. Replace wiring
d. None of the above

____ 4. How would you correct the problem of a voltage regulator?

a. Replace alternator
b. Replace voltage regulator
c. Replace wiring
d. None of the above

____ 5. How would you correct the problem of a defective battery?

a. Replace alternator with recommended replacement part
b. Replace voltage regulator
c. Repair alternator
d. None of the above

____ 6. Technician A has found dirty battery cables while checking for a low or no-charge complaint. Technician A says the battery should be replaced. Technician B says all of the circuit wiring needs to be cleaned and tightened. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 7. Technician A has found a faulty voltage regulator to be the problem while checking for an overcharge complaint. Technician A says the battery should be replaced. Technician B says the voltage regulator needs to be replaced. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 8. Technician A has found high resistance in the charging system circuit while checking for an undercharge complaint. Technician A says the battery should be replaced. Technician B says the alternator needs to be replaced. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 9. While checking a vehicle for faulty operation of the lights and other electrical options, loose wiring is found to be the cause. Which of the following is the solution to the problem?

a. Replace voltage regulator
b. Replace wiring
c. Replace connections
d. Inspect and repair wiring

____ 10. While checking a vehicle for a low or no charge condition the battery is found to be an incorrect size. Which of the following is the solution to the problem?

a. Replace voltage regulator
b. Replace with correct battery
c. Replace wiring
d. None of the above

Objective 14

Job Sheet 1—Inspect, Adjust, and Replace Alternator Drive Belts, Pulleys, and Tensioners

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

If a problem arises with an alternator, a visual inspection of the drive belts, pulleys, or tensioners is a prerequisite to other testing. Inspecting the drive belts, pulleys and tensioners of an alternator for wear or damage whenever the hood is open is a good habit to develop. Inspect components if a squealing or a flapping noise is reported by the client.

To check for a loose belt, press on the center of the belt with your thumb, or use a belt tension gauge. When testing with your thumb, the belt should flex about one-half inch. Refer to the tension gauge manufacturer's instructions for specifications. When inspecting the belt for looseness also check for deterioration, cracks, grease or oil contamination, and glazing. If the belt is damaged, replace it. If the belt is loose, tighten it only enough to prevent the belt from slipping or flapping. If the belt is tightened too much it may cause damage to the alternator.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Vise
- Replacement alternator drive belts, pulleys, and fans
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Belt tension gauge
- Safety glasses

Job Sheet 1

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before begining any servcice or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disconnect the battery negative cable.

☐ 6. Disconnect the alternator wires.

Note: Some wires can be disconnected by removing a nut and washer while others have connectors which are plugged.

☐ 7. Loosen the adjuster bolt and/or tensioner (if so equipped).

Note: Vehicles equipped with serpentine belts do not have adjuster bolts.

☐ 8. Loosen the drive belt by moving the alternator or the tensioner (if so equipped) in toward the engine.

☐ 9. Lift the drive belt from the alternator pulley.

☐ 10. Remove the loose adjuster bolt (if equipped) and mounting bolts by hand.

☐ 11. Lift the alternator from the vehicle.

☐ 12. Clamp the front rotor housing in a vise.

☐ 13. Hold the pulley shaft with an allen wrench and remove the drive pulley from the rotor shaft.

☐ 14. Remove the retainer nut and washer with an appropriate wrench.

☐ 15. Visually inspect the belts, pulleys, and fan for damage or wear.

☐ 16. Remove the old drive belt pulley and fan with an appropriate wrench.

☐ 17. Install a new drive belt pulley and fan.

☐ 18. Replace the drive pulley onto the rotor shaft. Clamp the front housing in the vise. Hold the pulley shaft with an appropriate wrench and tighten the retainer nut and washer.

☐ 19. Replace the alternator on the vehicle.

☐ 20. Replace the adjuster bolt (if equipped) and mounting bolts.

☐ 21. Replace the old drive pulley belt with a new drive pulley belt.

☐ 22. Adjust belt tension to manufacturer's specifications using a belt tension gauge.

☐ 23. Tighten the adjuster bolt and mounting bolts.

☐ 24. Reconnect the alternator wires.

☐ 25. Reconnect the battery negative cable.

☐ 26. Start vehicle. Verify repair.

☐ 27. Turn in job ticket when finished.

☐ 28. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 15

Job Sheet 2—Make a Charging System Output Test; Determine Needed Repairs

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

A charging system output test measures the maximum current the alternator can produce at a specified voltage or maximum load. A charging system output test should be done when low generator voltage and current is suspected. A load tester, VAT tester, or ammeter may be used to measure the current. Procedures differ with non-inductive testers. Always check the operating directions of the tester before connecting to charging components. When using an ammeter to perform an output test, calculate the charging system output by adding the two ammeter readings together and compare these figures with the manufacturer's specifications to determine needed tests and repairs. For instance, if the system tests low, a regulator voltage and regulator bypass test is usually required to determine if the alternator, regulator, or circuit wiring is at fault.

Some guidelines to prevent damage to the charging and other electrical systems when working with charging system components are:

Guidelines

- Disconnect the battery before removing any charging system component.
- Never reverse polarity when connecting jumper cables to the battery.
- Do **not** operate the alternator with the output disconnected.
- Never short or ground any charging system terminal.

Job Sheet 2

The output of the generator is sized or rated to meet the demands of the vehicle. For example, a vehicle with many accessories will have a higher amp size rating than a vehicle with a few accessories. Always check the size or rating of the alternator being tested in the appropriate service manual.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Load tester/ammeter/inductive amp gauge
- Other equipment and supplies as required by procedure
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 2

Objective 16

Job Sheet 3—Make a Charging Circuit Voltage Drop Test; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Introduction

A circuit voltage drop test will locate higher than normal resistance across a cable, component, or connection during current flow. It is performed when the charging system has failed. Wires or components do not need to be disconnected to check for internal voltage drops. A variety of testing equipment including a Multimeter/Voltmeter, Multimeter/Ammeter, Multimeter/Ohmmeter, and a VAT tester may be used to perform a charging circuit voltage drop test. When using a Multimeter/Voltmeter to perform a circuit voltage drop test, connect voltmeter leads at various connections along the regulator circuit. The voltage drop between the leads should not exceed 0.1 volts. If an excessive voltage drop is shown on the meter, the problem is located between the voltmeter leads. Replace damaged parts and/or tighten loose connections.

There are two common types of circuit voltage drop tests, one for an insulated circuit and one for a grounded circuit. Refer to the wiring diagram to identify the type of circuit being tested. To test, refer to the manufacturer's instructions for the tester, and connect as indicated.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Multimeter/Voltmeter
- Other equipment and supplies as required by procedure
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Job Sheet 3

Note: Preference should be given to the Technology and Maintenance Council (TMC) procedures if available. TMC procedures don't normally include cranking the engine/starter as part of the testing procedure. This prolongs the life of the starter.

Note: Procedures vary with the vehicle. Always check the procedure before beginning any service or repair.

Procedure

Insulated circuit

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Connect the voltmeter across the alternator output terminal and the positive battery terminal.

☐ 6. Run the vehicle at fast idle with all accessories turned off.

☐ 7. Turn the load control on the voltmeter to obtain a 20 amp current flow at 15 volts or less.

☐ 8. If an excessive voltage drop is shown on the meter, it indicates a high resistance between voltmeter leads.

☐ 9. Replace damaged parts and/or tighten loose connections.

☐ 10. After replacing damaged parts, check voltage reading again to confirm there are no problems.

Grounded circuit

☐ 1. Connect the voltmeter across the negative battery terminal and alternator housing.

☐ 2. Run the vehicle at fast idle with all accessories turned off.

☐ 3. Turn the load control on the voltmeter to obtain a 20 amp current flow at 15 volts or less.

☐ 4. If an excessive voltage drop is shown on the meter, it indicates a high resistance between voltmeter leads.

☐ 5. Replace burned plug socket, damaged parts, and/or tighten loose connections.

☐ 6. After replacing damaged parts, check voltage reading again to confirm there are no problems.

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

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Objective 17

Job Sheet 4—Test an S.I. Series Alternator

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- DVOM
- Ammeter 0-75 amp rating or higher
- Carbon pile
- Screwdriver
- Clean shop towels
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure before beginning any service or repair.

> Warning: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Test the battery.

Note: For valid tests, the battery must be at least half charged and in good condition.

☐ 6. Check alternator drive belt tension, and adjust as necessary.

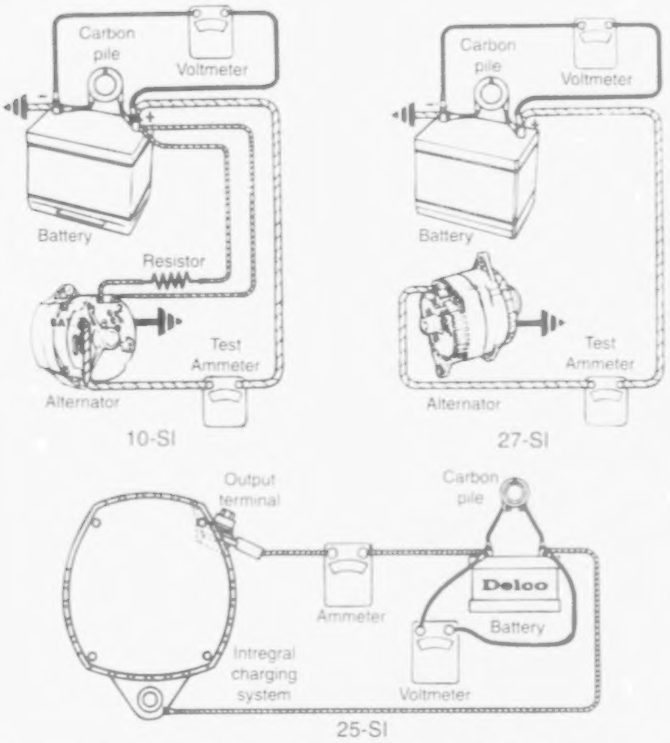
☐ 7. Check all charging system wiring for defects and all terminal connections for cleanliness and tightness.

Note: If all the above steps are satisfactory, check the alternator with the following procedure.

☐ 8. Disconnect battery ground cable.

☐ 9. Make test instrument connections for the type of alternator to be tested, as shown in Figure 1

Figure 1


Carbon pile
Voltmeter
Battery
Resistor
Test Ammeter
Alternator
Carbon pile
Voltmeter
Battery
Test Ammeter
Alternator
Output terminal
Carbon pile
Deloo
Ammeter
Battery
Intregral charging system
Voltmeter

10-SI

27-SI

25-SI

Reprinted with permission of Delco Remy Division, GM Corp.

Note: The hex bolt on the output terminal on the 25-SI alternator is electrically insulated.

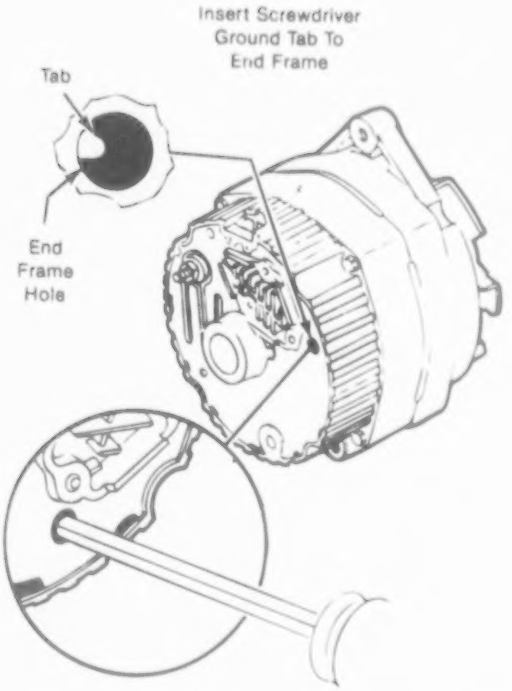
☐ 10. Operate engine at moderate speed, and adjust the carbon pile rheostat as required to obtain maximum current output.

Note: If ammeter reading is within 10 amps of rated output, the alternator and regulator are not defective. If ammeter reading is not within 10 amps of rated output, bypass regulator to see if the alternator or regulator is at fault.

☐ 11. Bypass regulators on 10-SI and 27-SI alternators (Figure 2)

Note: Ground the field winding by inserting a screwdriver into the test hole.

Figure 2



Warning: Tab is within 3/4 inch (19.05 mm) of the casting surface. Do not force screwdriver deeper into the end frame; severe damage to the alternator could result.

☐ 12. Bypass regulator on a 25-SI alternator.

- Remove field coil leads from the regulator.
- Ground one field lead and connect the other field lead to battery voltage.

☐ 13. Operate engine at moderate speed, and adjust carbon pile rheostat to obtain maximum current output.

Note: If current output is within 10 percent of rated output, replace the voltage regulator. If current output is not within 10 percent of rated output, remove alternator and bench test field windings, rectifier, and stator.

☐ 14. Turn engine off and disconnect all test instruments.

☐ 15. Turn in job ticket when finished.

☐ 16. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 4

Objective 18

Job Sheet 5—Inspect, Repair, or Replace Connectors and Wires of Charging Circuits

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

Visually inspecting connectors and wires of charging circuits for tightness, wear, and damage is a common practice when diagnosing charging system problems. Check the connection on the voltage regulator and the alternator for loose electrical connections or shorted wires. Move the wires around while running the engine. If the warning lamp goes out or the ammeter instrument indicates proper range, the problem is in the wire being jarred. A voltage drop test may be needed to test wiring along the charging system path.

When replacing connectors and/or wires, always refer to the appropriate service manual for exact procedure.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by procedure.

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

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☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________________

Technician ____________________

Supervisor ____________________

Job Sheet 5

Objective 19

Job Sheet 6—Remove, Inspect, and Replace an Alternator

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

During charging system tests, low voltage and current output problems may indicate a defective alternator. If a defective alternator is found to be the problem, the alternator will need to be replaced. In the past, alternators were serviced and repaired; now, however, alternators are replaced.

It is the rotors, brushes, stators, rectifier bridges, and cooling fans of the alternator that work together to create magnetic fields, produce current, and charge the system. Alternators all operate on the same principle. There are, however, differences in their construction and style. Different manufacturers will usually favor a different type of alternator. The alternator may be a front, side, or rear-connected alternator with a voltage regulator inside of it or located outside of it. Always refer to the appropriate vehicle service manual for specific type and style of alternator. Follow manufacturer's instructions when installing a new generator.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Belt tension gauge
- Alternator
- Other equipment and supplies as required by procedure
- Torque wrench
- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Removal

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Disconnect battery from the vehicle.

☐ 6. Disconnect wires at connector on alternator. Make a note of the location and any special insulating washers.

☐ 7. Loosen bolts.

☐ 8. Slide the belt off the alternator.

☐ 9. Lift alternator out of vehicle.

Installation

☐ 1. With the battery disconnected, place new alternator onto the engine.

☐ 2. Hand screw the bolts without tightening; connect wires first if needed.

☐ 3. After checking the condition of the belt and replacing it if needed, slip the belt on each pulley and align properly.

☐ 4. Adjust belt tension using belt tension gauge.

☐ 5. Tighten bolts.

☐ 6. Reconnect battery.

☐ 7. Start vehicle. Verify repair.

☐ 8. Turn in job ticket when finished. 1052

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Unit 8 Lighting Systems Diagnosis & Repair

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Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose the cause of problems with, and inspect, test, repair and replace components of headlights, daytime running lights, parking lights, clearance lights, taillights, stoplights, turn signal lights, hazard lights, back-up lights, instrument lights, and courtesy lights, aim headlight bulbs, and test and replace light bulbs. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to parts of headlights and daytime running lights circuits to descriptions of their functions.
2. Match terms related to parts of parking lights, taillights, clearance lights, and marker lights circuits to their functions.
3. Match terms related to parts of a stop light circuit to their functions.
4. Match terms related to parts of a turn signal and hazard lights circuit to their functions.
5. Match terms related to parts of back-up lights circuits to their functions.
6. Match terms related to parts of an instrument lighting circuit to their functions.
7. Match terms related to parts of a courtesy lights circuit to their functions.
8. Complete statements concerning the parts of a tractor-to-trailer multi-wire connector.
9. Diagnose the cause of headlights and daytime running lights problems. (Assignment Sheet 1)
10. Diagnose the cause of parking lights, clearance lights, and taillights problems. (Assignment Sheet 2)
11. Diagnose the cause of stoplight (brake light) problems. (Assignment Sheet 3)
12. Diagnose the cause of turn signals and hazard lights problems. (Assignment Sheet 4)
13. Diagnose the cause of back-up lights problems. (Assignment Sheet 5)
14. Diagnose the cause of instrument lighting problems. (Assignment Sheet 6)

15. Diagnose the cause of courtesy lights problems. (Assignment Sheet 7)
16. Inspect, replace, and aim headlights/bulbs. (Job Sheet 1)
17. Inspect, test, and replace light bulbs and test sockets. (Job Sheet 2)
18. Inspect, test, repair and replace the components of a headlights and daytime running lights circuit. (Job Sheet 3)
19. Inspect, test, repair and replace the components of a parking light, clearance light and taillight circuit. (Job Sheet 4)
20. Inspect, test, adjust, repair and replace the components of a stoplight (brake light) circuit. (Job Sheet 5)
21. Inspect, test, repair and replace the components of a turn signal and hazard lights circuit. (Job Sheet 6)
22. Inspect, test, repair and replace the components of a back-up lights circuit. (Job Sheet 7)
23. Inspect, test, repair and replace the components of an instrument lighting circuit. (Job Sheet 8)
24. Inspect, test, repair and replace the components of a courtesy lights circuit. (Job Sheet 9)
25. Inspect, test, repair and replace the components of tractor-to-trailer lights circuit. (Job Sheet 10)

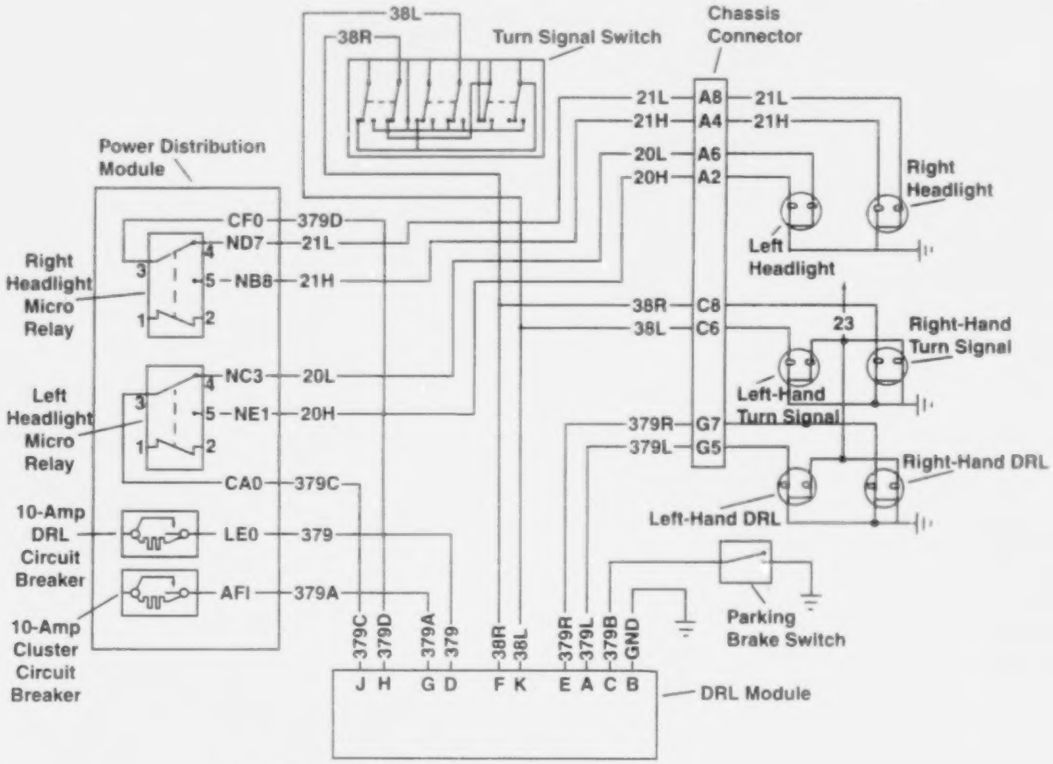
Information Sheet

Objective 1

Parts of a headlights and daytime running lights circuit and descriptions of their functions

Note: Headlights provide better visibilility in nighttime or poor-visibility driving conditions.

Figure 1


38L
38R
Turn Signal Switch
Chassis Connector
Power Distribution Module
Right Headlight Micro Relay
Left Headlight Micro Relay
10-Amp DRL Circuit Breaker
10-Amp Cluster Circuit Breaker
CF0
ND7
NB8
NC3
NE1
CA0
LE0
AFI
379D
21L
21H
20L
20H
379C
379
379A
A8
A4
A6
A2
C8
C6
G7
G5
379R
379L
Right Headlight
Left Headlight
23
Right-Hand Turn Signal
Left-Hand Turn Signal
Right-Hand DRL
Left-Hand DRL
Parking Brake Switch
379B
GND
J H G D F K E A C B
DRL Module

Courtesy of Freightliner LLC

a. **Battery**—provides electrical current directly to the headlight switch

Note: The charging system also plays a part in providing current to the lighting circuit.

b. **Circuit breaker**—protects components of the circuit from temporary current overloads

Note: Circuit breakers are sometimes found in the headlight circuit. The circuit breaker opens when excessive current is flowing into the circuit. When excessive current flow is present, the circuit breaker stops current flow to the headlight circuit turning off the headlights. Once cooled, the circuit breaker closes and returns current. Circuit breakers automatically reset themselves once the switch has been turned off.

c. **Connector**—plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

d. **Dimmer switch**—directs current flow to the high or low beam filaments of headlight bulbs

Note: On heavy duty vehicles, dimmer switches are mounted on the floor or steering column.

e. **Fusible link**—protects components of the circuit from excessive current flow

Note: The fusible link is usually found near the battery or starter. Current must pass through the fusible link before entering the headlight switch.

f. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

g. **Headlight**—illuminates when current is flowing to the filament of the bulb in the self-contained unit

Note: Components of the headlights consist of one or two bulbs with an outer prism lens (usually made of glass) and a reflective backing.

h. **Headlight relays**—uses a low current, provided by a switch, to control a higher current going to the headlights

i. **Headlight retaining screws**—fastens headlights in place

j. **Headlight switch**—controls current flow to the circuit

Note: The headlight switch is usually a three-position switch with an off, park, and headlights position located on the steering column or dashboard. Headlight switches usually have a rheostat to control the brightness of the instrument and panel lights.

k. **High-beam indicator light**—identifies if the high beam circuit is complete

Note: When the high-beam circuit is on, a switch closes to the high beam indicator lamp allowing the circuit to flow to the light bulb. The light bulb is usually located on the instrument panel and may be part of a printed circuit.

l. **Horizontal adjusting screw**—used to adjust the headlight beam from side to side

m. **Vertical adjusting screw**—used to adjust the headlight beam up and down

n. **Wiring**—connects components of the lighting circuit to the battery and/or each other

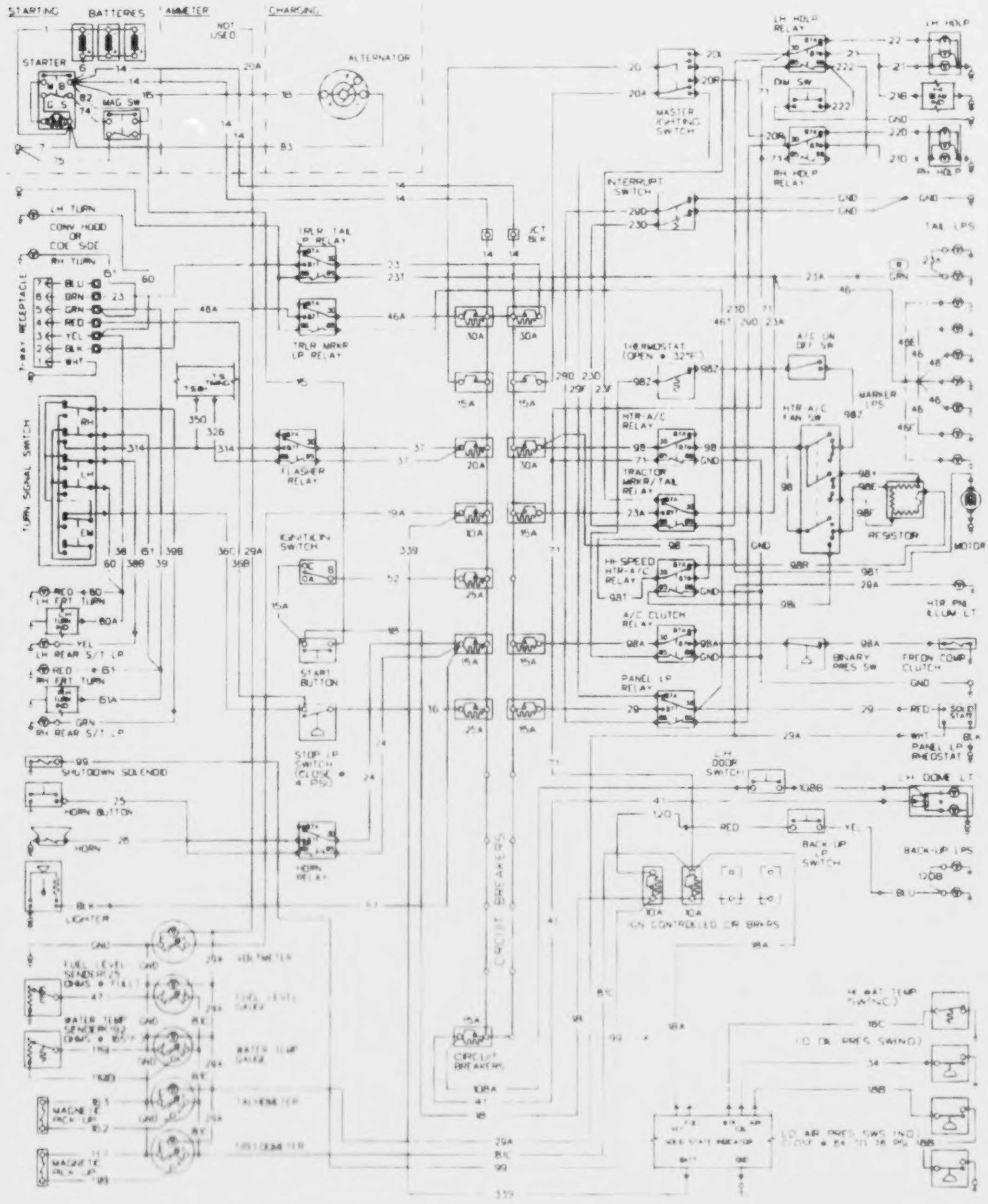
o. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

Objective 2

Parts of a parking lights, taillights, clearance lights and marker lights circuit and description of their functions

Note: Taillights allow the vehicle to be seen by other road users. Side marker lights help other drives determine the length and width of the vehicle. Clearance and marker lights outline the tractor and trailer.

Figure 2—Basic Wiring Diagram


STARTING
BATTERIES
AMMETER
NOT USED
CHARGING
ALTERNATOR
STARTER
MAG SW
LH HDLP RELAY
LH HDLP
DIM SW
RH HDLP RELAY
RH HDLP
MASTER LIGHTING SWITCH
INTERRUPT SWITCH
TAIL LPS
LH TURN
CONV HOOD OR COE SIDE
RH TURN
7-WAY RECEPTACLE
TRLR TAIL LP RELAY
TRLR MRKR LP RELAY
JCT BLK
THERMOSTAT (OPEN @ 32°F)
A/C ON OFF SW
MARKER LPS
HTR-A/C RELAY
HTR-A/C FAN SW
TRACTOR MRKR/TAIL RELAY
RESISTOR
MOTOR
TURN SIGNAL SWITCH
FLASHER RELAY
IGNITION SWITCH
HI-SPEED HTR-A/C RELAY
HTR PNL ILLUM LT
A/C CLUTCH RELAY
BINARY PRES SW
FREON COMP CLUTCH
LH FRT TURN
LH REAR S/T LP
RH FRT TURN
RH REAR S/T LP
START BUTTON
PANEL LP RELAY
PANEL LP RHEOSTAT
STOP LP SWITCH (CLOSE @ 4 PSI)
SHUTDOWN SOLENOID
HORN BUTTON
HORN
HORN RELAY
LH DOOR SWITCH
LH DOME LT
BACK-UP LP SWITCH
BACK-UP LPS
LIGHTER
CIRCUIT BREAKERS
IGN CONTROLLED CIR BRKRS
VOLTMETER
FUEL LEVEL SENDER
FUEL LEVEL GAGE
WATER TEMP SENDER
WATER TEMP GAGE
TACHOMETER
MAGNETIC PICK-UP
SPEEDOMETER
HI WAT TEMP SW(NC)
LO OIL PRES SW(NO)
LO AIR PRES SWS (NO)
SOLID STATE INDICATOR

Courtesy of Freightliner LLC

a. **Clearance/marker lights**—lights designed to outline the tractor, straight truck body, or trailer dimensions

b. **Circuit breaker**—protects components of the circuit from short circuits and current overloads

Note: Circuit breakers are usually found under the dashboard, in the storage box, in the cab housing or engine compartment, or in the foot well. They are located in a box or panel.

c. **Connector**—plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

d. **Fusible link**—protects components from excessive current flow

Note: The fusible link is usually found near the battery. Current must pass through the fusible link before entering the headlight switch.

e. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

Note: Most exterior taillights share a common ground connection.

f. **Headlight switch**—controls current flow to the circuit

Note: When the headlight switch is turned to the park or on position, current flows from this switch to the taillight bulbs and side marker bulbs.

g. **License plate light/bulb circuit**—illuminates the license plate

Note: Usually part of the parking and taillights circuit, the license plate circuit uses relays to provide current flow to a bulb located over the license plate.

h. **Parking lights**—provides illumination for parking the vehicle

i. **Relay**—an electrical switch that allows a small current to control a much larger one

j. **Taillights**—provides illumination for the stop, tail, directional, backup and license plate systems

Note: Many rear light bulbs are a combination bulb containing stop and taillight filaments. Some circuits are two bulb circuits and some are three bulb circuits. The circuit may use one or more bulbs for multipurpose. For instance, on a three bulb circuit the taillight, parking lights, and turn signal share one bulb. Bulbs may be single filament or dual filament bulbs.

k. **Wiring**—connects components of the lighting circuit to the battery and/or each other

l. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

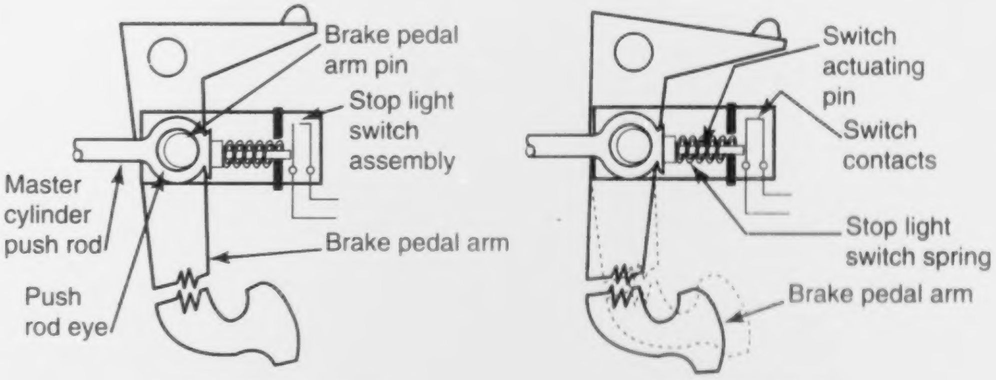
Information Sheet

Objective 3

Parts of a stoplight (brake light) circuit and descriptions of their functions (see figure 5)

Note: The brake light is used to warn other drivers that the vehicle is stopping or braking.

Figure 3—Typical stop light switch

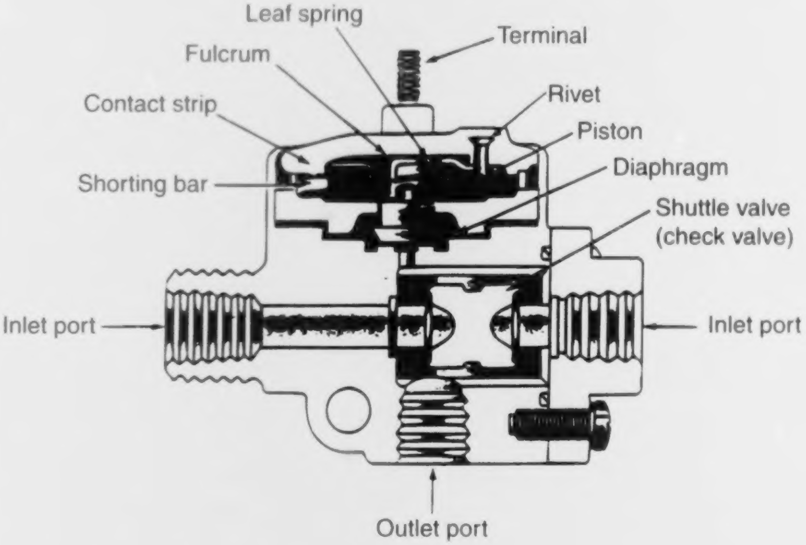

Brake pedal arm pin
Stop light switch assembly
Master cylinder push rod
Push rod eye
Brake pedal arm
Switch actuating pin
Switch contacts
Stop light switch spring
Brake pedal arm

Brakes NOT applied

Brakes applied

Used with permission of Ford Motor Co.

Figure 4—Stoplight switch on air brake equipped truck


Leaf spring
Terminal
Fulcrum
Rivet
Contact strip
Piston
Diaphragm
Shorting bar
Shuttle valve (check valve)
Inlet port
Inlet port
Outlet port

a. **Brake pedal**—a tactile sensor reacting to the amount of pressure applied to activate the brake switch

1004

b. **Brake light bulbs**—illuminates the taillight unit

Note: Brake light bulbs are usually high intensity filaments and are part of a dual filament bulb. Brake light bulbs are wired in parallel. All brake lights must be red.

c. **Brake switch (electric)**—allows current to flow to the brake light bulbs

Note: There are two major types of switches used in medium/heavy-duty brake light circuits. The brake pedal switch is attached to the brake pedal, and the air brake switch is located on the air brake line.

d. **Brake switch (air)**—An electro-pneumatic switch that operates in conjunction with the brake valve to complete the circuit to the brake light bulbs

e. **Fuse**—protects components of the circuit from short circuits and current overloads

Note: The brake light receives power directly from the battery through a fuse or circuit breaker allowing the brake light to operate even when the ignition switch is in the off position.

f. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

Note: The ground wire is located on the light bulb of the brake light circuit.

g. **Turn-signal switch**—allows current to flow to the turn signal light bulbs

Note: The turn-signal switch is usually located on the steering column.

h. **Wiring**—connects components of the lighting circuit to the battery and/or each other

i. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

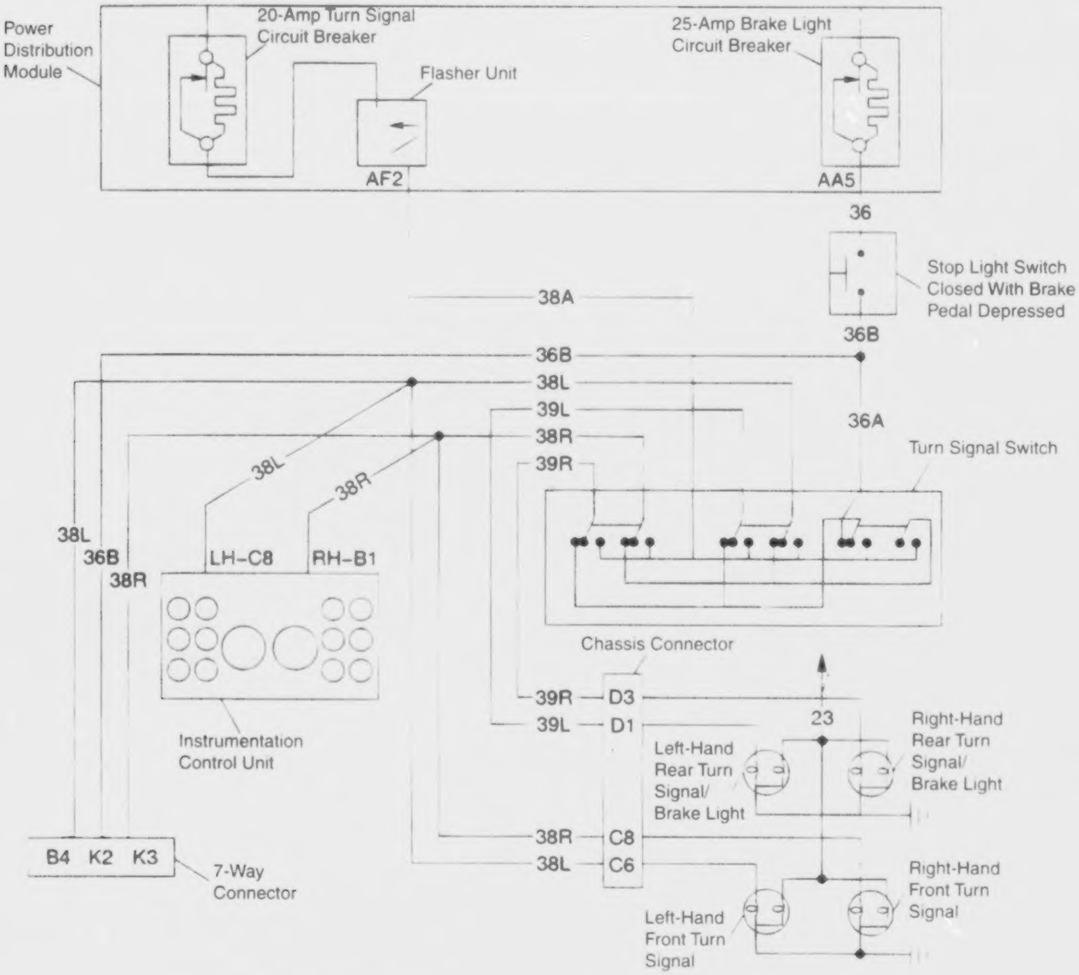
Information Sheet

Objective 4

Parts of a turn signal and hazard lights circuit and descriptions of their functions.

Note: Turn signals indicate the driver's intention to change lanes or to change direction. Hazard lights flash off and on warning oncoming traffic of a possible emergency hazard.

Figure 5


Power Distribution Module
20-Amp Turn Signal Circuit Breaker
Flasher Unit
25-Amp Brake Light Circuit Breaker
AF2
AA5
36
Stop Light Switch Closed With Brake Pedal Depressed
38A
36B
36B
38L
39L
38R
39R
36A
Turn Signal Switch
38L
38R
38L
36B
38R
LH-C8
RH-B1
Instrumentation Control Unit
Chassis Connector
39R
D3
39L
D1
23
Left-Hand Rear Turn Signal/ Brake Light
Right-Hand Rear Turn Signal/ Brake Light
38R
C8
38L
C6
B4
K2
K3
7-Way Connector
Left-Hand Front Turn Signal
Right-Hand Front Turn Signal

Courtesy of Freightliner LLC

a. **Flasher unit**—opens and closes the turn signal circuit providing intermittent current to the side turn signal light bulbs, taillights, and instrument panel lights

Note: Some medium/heavy-duty vehicles may employ two flasher units. One unit is used to operate the directional signals and the other to operate the hazard lights.

1003

b. **Turn signal light bulbs**—illuminates the turn signal and hazard circuit

c. **Fuse**—protects components of the circuit from short circuits and current overloads

d. **Indicator bulbs**—alerts the driver to the direction of the electrical current flowing to the signal lights

e. **Turn-signal switch**—guides current to the right or left front and rear of the vehicle taillights

Note: Some vehicles have a lane-change directional signal switch that allows the driver to hold down on the turn signal light switch lever to signal a lane change. When the driver releases the lever the signal is cancelled immediately.

f. **Wiring**—connects components of the lighting circuit to the battery and/or each other

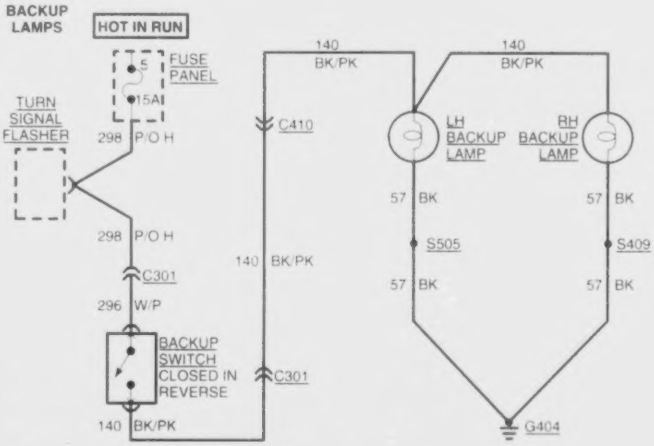
g. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

Objective 5

Parts of a back-up lights circuit and descriptions of their functions

Note: The back-up lights circuit illuminates the area behind the vehicle when the transmission is shifted into reverse.

Figure 6


BACKUP LAMPS
HOT IN RUN
FUSE PANEL
5
15A
TURN SIGNAL FLASHER
298 P/O H
298 P/O H
C301
296 W/P
BACKUP SWITCH CLOSED IN REVERSE
140 BK/PK
C301
140 BK/PK
C410
140 BK/PK
140 BK/PK
LH BACKUP LAMP
RH BACKUP LAMP
57 BK
S505
57 BK
57 BK
S409
57 BK
G404

Used with permission of Ford Motor Co.

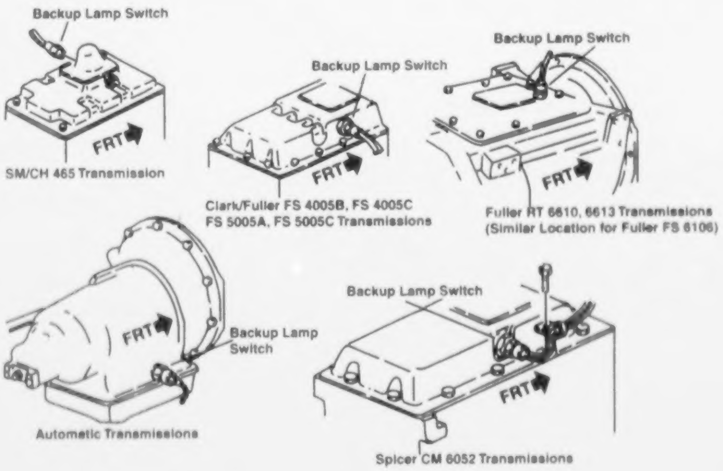
a. **Back-up light bulbs**—illuminates the taillight unit

b. **Back-up light switch**—allows current to flow to the back-up light bulbs when the transmission mounted switch is shifted into reverse

c. **Fuse**—protects components of the circuit from short circuits and current overloads

d. **Gear shift or transmission switch**—allows current to flow to the back-up light switch when the transmission is shifted into reverse

Figure 7


Backup Lamp Switch
SM/CH 465 Transmission
Backup Lamp Switch
Clark/Fuller FS 4005B, FS 4005C
FS 5005A, FS 5005C Transmissions
Backup Lamp Switch
Fuller RT 6610, 6613 Transmissions
(Similar Location for Fuller FS 6106)
FRT
Backup Lamp Switch
Automatic Transmissions
Backup Lamp Switch
Spicer CM 6052 Transmissions

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e. **Wiring**—connects components of the lighting circuit to the battery and/or each other

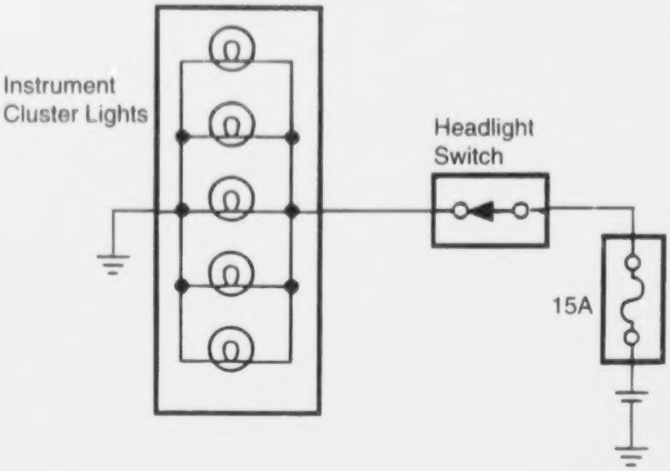
f. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

Objective 6

Parts of an instrument lighting circuit and descriptions of their functions

Note: Instrument lighting circuits use a cluster of lights to warn the driver of potentially dangerous conditions, indicate turn signals, and provide indirect light for the driver to see the instrument gauges, climate controls, audio, and other controls.

Figure 8



a. **Connector**—plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

Note: Relays may be connected to other relays in the instrument light circuit with a connector.

b. **Fiber optic conductors**—insulates the fiber optic strands

c. **Fiber optic strands**—reflects the light from the panel illumination bulbs to lens on the instrument panel

d. **Fuse**—protects components of the circuit from short circuits and current overloads

Note: The circuit is usually protected by a 10- or 15-amp fuse located in the circuit breaker panel.

e. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

f. **Headlight switch**—controls current flow to the circuit

Note: The instrument lighting circuit is controlled by the contacts in the headlight switch. When the headlight switch is in the park or on position, rotating it can increase or decrease the brightness of the instrument lighting bulbs. A rheostat may be located by itself on the dash or in the headlight switch.

g. **Panel illumination light bulbs**—provides indirect lighting to illuminate the instrument panel

Note: The instrument panel bulbs operate independently from one another. Connected parallel to the battery so when one bulb burns out the other bulbs remain illuminated.

h. **Printed circuit board**—instrument light bulbs, fiber optics, and circuits printed on a panel board

i. **Relay**—controls current by switching current on and off rapidly to the panel light circuit

j. **Rheostat**—increases or decreases current flow to instrument panel bulbs to control brightness.

Note: This rheostat may be operated by the headlight switch or by a separate control.

k. **Wiring**—connects components of the lighting circuit to the battery and/or each other

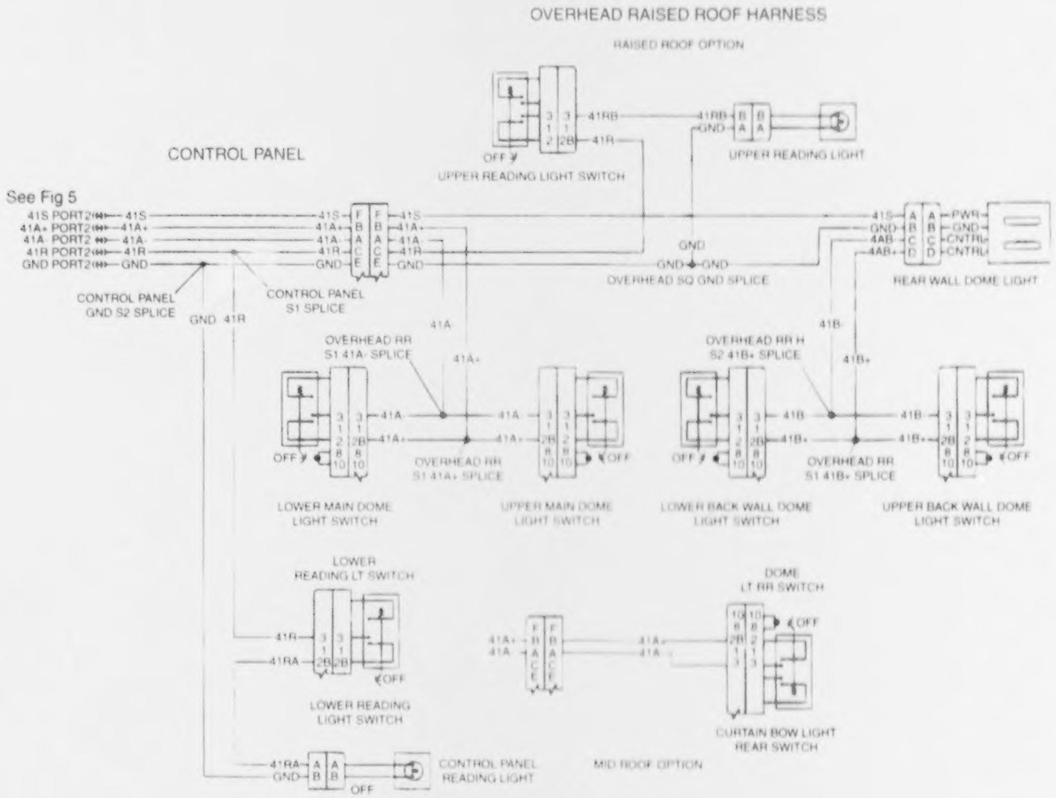
l. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

Objective 7

Parts of a courtesy lights circuit and descriptions of their functions

Note: The interior courtesy lights, storage box light, dome light, and map lamp make up the courtesy light circuit. These lights provide the driver with light when the condtions are poor or dark. Some lights illuminate the vehicle when the door is opened. Some lights illuminate specific areas of the vehicle like the baggage compartment.

Figure 9


OVERHEAD RAISED ROOF HARNESS
RAISED ROOF OPTION
CONTROL PANEL
See Fig 5
41S PORT2 41S
41A+ PORT2 41A+
41A- PORT2 41A-
41R PORT2 41R
GND PORT2 GND
41RB
41R
GND
OFF
UPPER READING LIGHT SWITCH
UPPER READING LIGHT
PWR
CNTRL
4AB-
4AB+
REAR WALL DOME LIGHT
OVERHEAD SQ GND SPLICE
CONTROL PANEL GND S2 SPLICE
CONTROL PANEL S1 SPLICE
41A-
41A+
41B-
41B+
OVERHEAD RR S1 41A- SPLICE
OVERHEAD RR S1 41A+ SPLICE
OVERHEAD RR H S2 41B+ SPLICE
OVERHEAD RR S1 41B+ SPLICE
LOWER MAIN DOME LIGHT SWITCH
UPPER MAIN DOME LIGHT SWITCH
LOWER BACK WALL DOME LIGHT SWITCH
UPPER BACK WALL DOME LIGHT SWITCH
LOWER READING LT SWITCH
41RA
LOWER READING LIGHT SWITCH
DOME LT RR SWITCH
CURTAIN BOW LIGHT REAR SWITCH
MID ROOF OPTION
CONTROL PANEL READING LIGHT

Courtesy of Freightliner LLC

a. **Cigar lighter**—provides electric current to accessories or to heat the metal coil of the lighter

Note: The cigar lighter may have a circuit breaker to protect it and be on a separate fuse from other loads in the courtesy light circuit. It is usually connected in series to the circuit.

b. **Connector**—plastic component containing one or more metal terminals that attach wires and wiring harnesses to electrical components and other harnesses

Note: The courtesy light circuit usually has a courtesy light connector and dome light connector in addition to the connector from the battery to the headlight switch.

c. **Door-jam switches**—connects current to ground

Note: In most vehicles the door jam switch is grounded to the frame of the vehicle by a ground wire. When the door is open the SPST switch closes and the circuit is completed. When the door closes the switch opens and breaks the currents path to the ground. However some makes and models use a single wire to complete the circuit to ground.

d. **Fuse**—protects components of the circuit from short circuits and current overloads

e. **Baggage compartment bulb**—illuminates the baggage compartment

Note: In most vehicles the baggage box bulb is operated by an SPST switch. When the door is open the switch closes and current is connected to ground through the light bulb, completing the circuit.

f. **Ground switch**—connects current to ground wire

Note: A fused battery connection supplies power to the left and right courtesy light bulbs with a ground-side switch. When the door opens, the door-jam switch closes providing a ground for the light bulbs. In some vehicles the bulbs may be connected to the ground by a ground wire from each light bulb instead of a ground switch.

g. **Headlight switch**—connects current flow to the circuit

h. **Left and right courtesy lights**—light bulbs that illuminate the left and right side of the interior of a vehicle when the door is open or when the headlight switch is rotated to a counter clockwise position

i. **Reading/Map light**—illuminates a specific interior area with an intense light

Note: The reading/map light bulb is operated by a grounded switch. When the switch is closed the ground wire accepts the flow of electricity, providing the positive-end point necessary to maintain the flow of electricity through the circuit.

j. **Wiring**—connects components of the lighting circuit to the battery and/or each other

k. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

1072

Objective 8

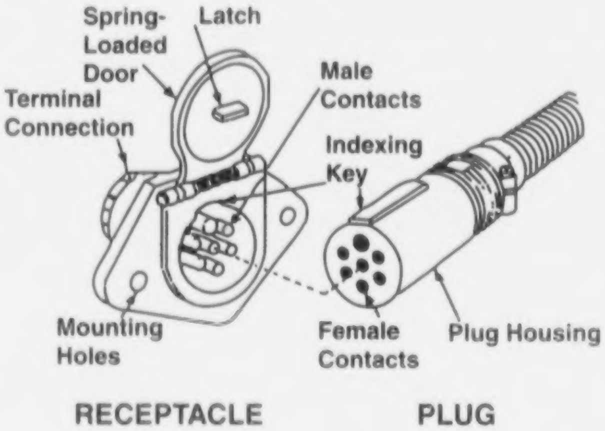
Parts of a tractor-to-trailer multi-wire connector

Note: The seven-conductor electrical plug and receptacle are sometimes referred to as a seven-pin or a seven-pole plug or receptacle.

a. **Seven-conductor electrical plug**—connector with seven female contacts used in conjunction with the receptacle to complete the lighting circuit to the trailer

b. **Seven-conductor electrical receptacle**—connector with seven male contacts used to make contact with the seven-conductor electrical plug

Figure 10


Spring-Loaded Door
Latch
Terminal Connection
Male Contacts
Indexing Key
Mounting Holes
Female Contacts
Plug Housing
RECEPTACLE
PLUG

c. **Junction block**—located at the instrument panel, this is where the trailer wiring harness usually connects to the electrical system

d. **Wiring harnesses**—a grouping of wires which are routed to specific areas of the vehicle and enclosed in conduit

Note: On 1997 and newer vehicles, there will be a supplemental connector (yellow) for the trailer ABS system. The green seven-conductor electrical plug shown in Figure 13 is used for trailer lighting.

Student Supplement 1—Lighting Systems

Lighting systems are an integral part of vehicle safety and must meet standard requirements regulated by federal law and/or state law. In accordance to safety laws, many manufacturer's lighting systems function about the same. Interior and exterior lights add to the safety of the driver, passengers of the vehicle, people in other vehicles, and pedestrians. Interior lights may include the dome light, courtesy lights, and instrument lights. Exterior lights may include headlights, turn signal lights, clearance lights, parking lights, stoplights, back-up lights, side marker lights, and running lights. These lighting systems may flash, dim, or illuminate to fulfill their purpose of providing maximum safety and optimum driving visibility. For example, headlights provide better visibility by projecting a beam of light on the road ahead, signal lights flash to signal other drivers of which direction the vehicle is turning, and interior lights illuminate instrument panels and the vehicle's interior for the driver's convenience and safety.

A lighting circuit will include many of the common electrical components studied in previous units. A lighting circuit will have a power source, protection device, conductor, load, control device and ground. These components are tested using basic testing methods you have learned in previous units on circuit and battery repair. Wiring diagrams, component locators, and service manuals assist the Electrical System Technician in recognizing the location of these common electrical components in the various lighting circuits.

The construction of the lighting circuits may be different in various makes and models of vehicles but the lighting systems will be similar in operation and diagnosis. Understanding the purpose and operation of various lighting circuits is essential to the Electrical Systems Technician when diagnosing and repairing lighting systems.

Student Supplement 2—Headlight Diagnosis Chart

CONDITION	POSSIBLE CAUSE	CORRECTIVE ACTION
Brighter than normal	Excessive current flow	Charging rate may be excessive; check voltage regulator. Replace if defective.
	Headlights out of adjustment	Aim headlights and adjust according to appropriate service manual.
Intermittent	Shorted condition in wiring, corrosion, loose connection, wear, or damage of headlight wiring	Inspect, test for shorts, repair, and/or replace wiring. Clean and tighten connectors.
	Defective dimmer switch	Measure voltage drop with a voltmeter or DVOM across the dimmer switch. If test shows high voltage drop, switch is defective. Replace switch.
	Defective headlight switch	Measure voltage drop with a voltmeter or DVOM across the headlight switch. If test shows high voltage drop, switch is defective. Replace switch.
	Defective circuit breaker	Use a test light to test circuit breaker. If defective, replace.
	Faulty light socket	Clean socket, test for continuity, and replace if needed.
Dim	Resistance in headlight circuit	Measure voltage drop with voltmeter or DVOM across possible problem component(s). If voltage drop exceeds .1 volts, component is defective. Replace component.
	Connectors and/or sockets	Inspect for corroded connectors and sockets. Clean, tighten and/or replace as needed.
	Charging rate too low	Check voltage regulator with voltmeter or DVOM. Replace if defective.
	Defective battery	Inspect and clean battery connections and wiring. Check electrolyte level. Charge and test battery. Replace if defective.

Continued on next page

Student Supplement 2

CONDITION	POSSIBLE CAUSE	CORRECTIVE ACTION
No operation	Burned out bulb(s)	Replace bulb(s).
	Defective headlight switch	Headlight switches can be tested two ways—testing for voltage at certain terminals and testing for continuity between certain pairs of terminals. If voltage testing, test with wiring connector in place. If continuity testing, the switch may be removed. If voltage does not register, the switch is defective and must be replaced. Test the switch at all terminals. Some manufacturers supply a continuity chart for use in testing headlight switches.
	Open circuit	Inspect for broken wire, disconnected electrical connections. Test circuit with a test light. Start at end of circuit and go to the other end of the circuit to locate possible cause
	Fusible link	If fusible link is burned or broken, replace.
	Fuse	If the fuse is blown, replace it. If the replacement fuse blows, check for a short circuit. Locate and repair short circuit.
	Defective battery	Inspect and clean battery connections and wiring. Check electrolyte level. Test and charge battery. Replace if defective.

Student Supplement 3—The Headlight Switch

Some lighting circuits are connected directly to the battery through the headlight switch. The headlight switch may be a single switch or a part of a combination switch located on the steering column of the vehicle. When it's on the dashboard, it is usually a three position push-pull switch with an off, park, and headlights position. When it's part of a combination switch on the steering column, it's a three position rotating switch.

The off position of the headlight switch breaks the current flow to the headlight circuit. The park position of the headlight switch allows current to flow to the parking, instrument, and interior lights circuits. The headlights position causes current to flow to the headlights and other related wiring. Headlight switches can also have a rheostat to control the brightness of the instrument and panel lights. It is activated when the headlight switch is rotated.

A test light or voltmeter will help you quickly determine if the headlight switch is good. Manufacturers usually include a headlight switch continuity chart in the service manual of a vehicle to identify the terminals that should be tested for continuity. When continuity is being tested, the switch can be removed from the vehicle and tested. When voltage is being tested, the switch should remain connected to the battery. However, you must know the terminal designations of the switch in order to test either the continuity or the voltage in the circuit. Refer to the appropriate service manual for a wiring diagram.

If the switch is good, test the relays between the headlight switch and the bulbs. If the switch is bad, replace it. To remove a headlight switch always refer to the appropriate service manual for removal procedure. When the headlight switch is on the steering column, the plastic cover around the column may need to be removed. When the switch is attached under the dash, the wiring connector will need to be unplugged. In older models a wheel puller may be needed to remove the steering wheel in order to test or replace the switch. In models with air bags, the air bag system may need to be disabled. Always refer to the appropriate service manual for correct procedure.

The headlight switch may be part of a combination switch with the turn signal, washer-wiper, and other switches or it may be by itself. The headlight switch may also input electrical signals to a microprocessor as part of the security, theft, or indicator systems. Refer to the appropriate service manual for a wiring diagram or a pictorial drawing showing the function of combination switches.

Student Supplement 4—Feedback

Feedback is the result of current traveling the path of least resistance in a circuit, sometimes activating another component other than the one intended. Wear, damage, or corrosion of a connector or conductor, and blown fuses may force the electrical current to travel to lights in the path of the current.

Blown fuses play a big role in feedback problems. A blown cigar lighter fuse may cause the dome light in a vehicle to get brighter when the doors are open and the courtesy lights to go out. A blown dome light fuse may cause the current which should be directed to the courtesy, dome light, taillights, running lights, and parking lights to travel back to the headlight switch. If the headlight switch is open, the current travels to the instrument light circuit and lights the bulbs that are connected in series to one another. However, the current is usually not strong enough to heat the filaments to a bright light. Therefore, the lights will be dimly lit.

Conductive corrosion is another cause for electrical current to activate a component(s) other that the one intended. Conductive corrosion happens when one conductor corrodes allowing current to flow from one conductor to another conductor. Any connection along the circuit path is subject to corrosion. Water, road shock, or natural wear may cause the common connection to short and cause feedback. For example, the dual-filament taillight bulb socket is corroded. The shared conductor in the connection may cause feedback to the windshield wiper motor, dome light, courtesy light and instrument lights because the different circuits share a common connector. The connector may provide ease of assembly or diagnosis and repair of different electrical components.

It is important to know the common connectors within the lighting circuit you are checking for feedback. Refer to appropriate service manual for wiring diagrams, components locators, and detailed drawings. Look at the wiring diagram shown in Figure 1. The letter C followed by a number identifies the terminals connecting to the headlight switch. All C707 designations are housed in the single shell of the connector as indicated by the dotted lines and common connector number. A detail drawing might give the visible layout of the connector and the location of the connector as shown in Figure 1 on the next page.

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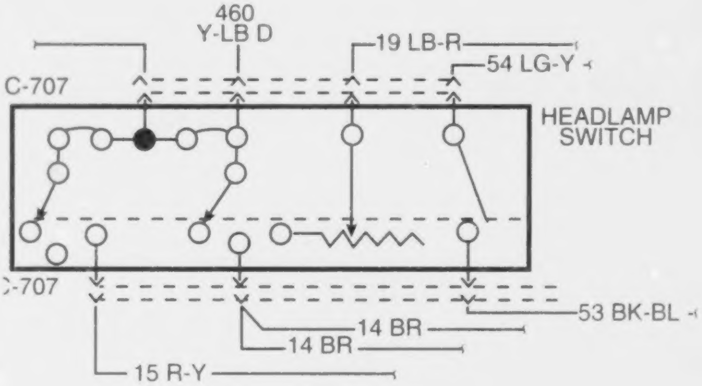
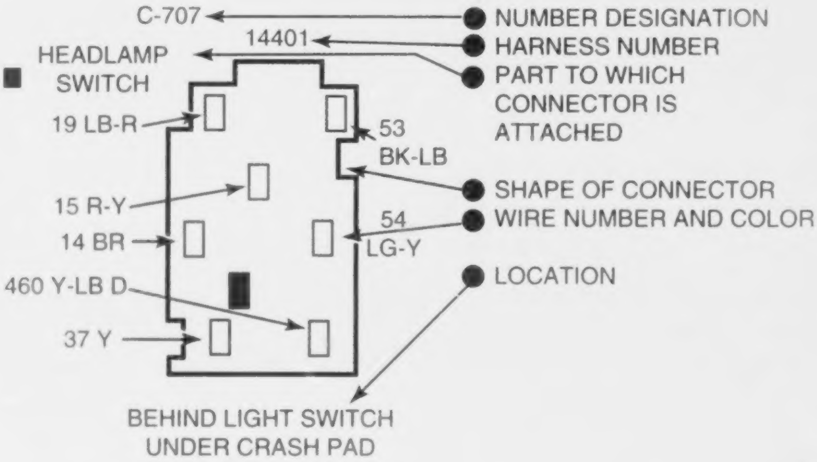

460
Y-LB D
19 LB-R
54 LG-Y
C-707
HEADLAMP
SWITCH
C-707
53 BK-BL
14 BR
14 BR
15 R-Y


C-707
14401
HEADLAMP
SWITCH
19 LB-R
15 R-Y
14 BR
460 Y-LB D
37 Y
53
BK-LB
54
LG-Y
NUMBER DESIGNATION
HARNESS NUMBER
PART TO WHICH
CONNECTOR IS
ATTACHED
SHAPE OF CONNECTOR
WIRE NUMBER AND COLOR
LOCATION
BEHIND LIGHT SWITCH
UNDER CRASH PAD

Used with permission of Ford Motor Co.

Student Supplement 5—Turn Signal and Hazard Light Malfunction Chart

ONE SIDE DOES NOT FLASH	SYSTEM DOES NOT FLASH ON EITHER SIDE	HAZARD WARNING MALFUNCTION-- SYSTEM DOES NOT FLASH	INDICATOR LAMP BRIGHT, EXTERNAL LAMPS DIM and SLOW or NO FLASH	INDICATOR LAMP BRIGHT, EXTERNAL LAMP DOES NOT LIGHT	INDICATOR LAMP DOES NOT LIGHT, EXTERNAL LAMPS OPERATE PROPERLY	SYSTEM DOES NOT CANCEL AFTER COMPLETION OF TURN
faulty external bulb	faulty fuse	faulty fuse	loose or corroded external bulb connection	open circuit in wire to external lamp	faulty indicator bulb in instrument cluster	broken canceling finger on switch
poor ground at bulb	faulty flasher unit	faulty flasher	poor ground circuit at external lamp			tilt only, one or both cancel springs missing
open circuit in wiring to external bulb	loose bulkhead connector	open circuit in feed wire to switch				improperly aligned canceling cam
faulty contact in switch	open circuit to flasher unit open circuit in feed wire to turn signal switch	faulty contact in switch open or grounded circuit in wiring to external bulbs				broken or loose canceling cam
	faulty switch connections					
	faulty connection in switch					
	open or grounded circuit in wiring to external bulbs					

Student Supplement 6—Trailer Lighting

Trailers are secured to the tractor by the fifth wheel located on the tractor frame. There are four connections that must be made in order for the trailer lights and brakes to function.

a. Air brake service glad hand

b. Air brake emergency glad hand

c. Electrical wiring cable harness

d. ABS wiring cable harness (if equipped)

Note: On 1997 and newer vehicles, there will be a supplemental connector (yellow) for the trailer ABS system. The green seven-conductor electrical plug shown in Figure 1 is used for trailer lighting.

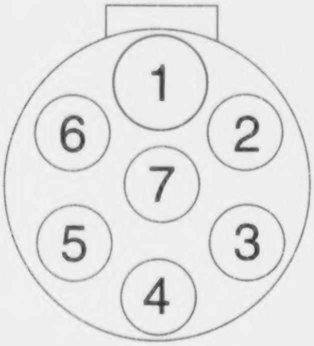
The actual location of the clearance, marker, and taillights on any trailer depends not only on the actual type of trailer body and its shape, but on TMC (Technology Maintenance Council) and ATA (American Trucking Association) RP-702 — Dimensional Placement of Trailer Lighting. All lighting must conform to FHWA (Federal Highway Administration) and FHTSA (Federal Highway Traffic Safety Administration) regulations. Consequently, all trailer manufacturers must comply with these lighting standards.

Trailer lighting and wiring specifications in North America generally use a seven-conductor tractor-to-trailer plug and receptacle (Figures 1 & 2). Plugs and receptacles for heavy-duty trailer units must conform to TMC/ATA RP-107, SAE (Society of Automotive Engineers) wiring gauge standard J-1067, and SAE standard J-560. The force required to connect or disconnect a plug from a receptacle should not exceed 50 pounds, and the cable and plug should be capable of withstanding a straight line pull of 150 pounds.

Correct selection of wire/cable size is a very important consideration that is sometimes overlooked, particularly when a trailer is being rebuilt or repaired. A 10% drop in battery power from the tractor to the trailer due to wire resistance can result in a 30% loss in illumination at the trailer lights. Voltage drop from the tractor to the trailer and throughout the length of the trailer can be kept to a minimum by selecting the proper wire gauge size.

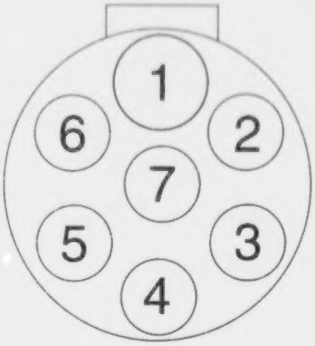
Student Supplement 6

Figure 1—J560 Connector on Trailer



Number	Color	Function
1	White	Ground (shared)
2	Black	Marker Lights
3	Yellow	Left Turn Indicator Lights
4	Red	Stop Lights
5	Green	Right Turn Indicator Lights
6	Brown	Tail Lights
7	Blue	ABS Power (new) or Auxiliary, Switched (old)

Figure 2—J560 Yellow Connector on Trailer



Number	Color	Function
1	White	Ground (shared)
2	Black	Optional
3	Yellow	ABS Malfunction Light
4	Red	Optional
5	Green	Optional
6	Brown	Optional
7	Blue	ABS Power

Objective 9

Assignment Sheet 1—Diagnose the Cause of Headlights and Daytime Running Lights Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Critical Thinking

Directions

Review and use the information found in Student Supplements 1, 2 and 3, *Lighting Systems*, *Headlight Diagnosis Chart* and *The Headlight Switch*, and the introduction to Job Sheets 1 and 2 to answer the following questions. Write your answer in the blank provided.

____ 1. The headlights on a vehicle flicker off and on. Technician A says the problem is probably caused by a short to ground. Technician B says the problem is probably caused by a short in the dimmer switch. Who is correct?

   a. Technician A
   b. Technician B
   c. both Technician A and B
   d. neither Technician A nor B

____ 2. Which of the following statements are not a part of guidelines for headlight adjustment screws?

   a. Seat a person in the driver's seat and the passenger seat.
   b. Rock the vehicle from side to side and front to back to allow the springs to come to rest.
   c. Check with the vehicle's service manual to determine whether or not the fuel tank should be half full or full.
   d. Inflate the tires to the recommended pressure.

Assignment Sheet 1

____ 3. A client complains that both headlights will not work. The headlight bulbs have tested good. Technician A says it is probably best to check the connector, fuse, and relay. Technician B says it is probably a defective ignition switch. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. When the headlights are dim, there is a resistance in the circuit. Technician A says the problem can be found by testing the voltage drop with a voltmeter across various parts of the circuit. Technician B says a wire could be loose or a connector could be corroded. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. A vehicle's headlights need adjusting. Technician A says headlight aiming can be done several ways but mechanical aimers can be used on all makes and models. Technician B says the headlight screen and aimers are accurate but the appropriate service manual instructs the best method to use for the vehicle. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. The headlights/bulbs of a vehicle are burned out. Technician A says when replacing a bulb it should be handled by the base to avoid damage to the bulb. Technician B says the bulb should be allowed to cool before holding it at the base. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. A vehicle with a short in the wiring can cause intermittent lighting damage. Technician A says when only one light is flicking on and off the test should begin at or near that bulb. Technician B says the problem is at the beginning of the circuit. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 8. When adjusting headlights using a headlight screen, how far must the vehicle be from the screen?

a. 15 feet
b. 20 feet
c. 25 feet
d. None of the above

____ 9. A fuse that is blown may cause the headlight system of a vehicle to fail. Once the fuse has been replaced with a correct current rating fuse and it blows again, which of the following possible causes and corrective actions are indicated next?

a. Short in the circuit, locate and repair
b. Short in the circuit, replace battery terminals
c. Defective headlight switch, replace switch
d. Defective dimmer switch, replace switch

____ 10. Technician A says a headlight switch must be removed to be tested. Technician B says it depends on the type of testing and is never removed when testing for voltage. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 10

Assignment Sheet 2—Diagnose the Cause of Parking Lights, Clearance Lights, and Taillights Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading

Critical Thinking

Introduction

Most parking lights, clearance lights and taillight problems are lights that dim, get brighter, and/or fail to operate. When the lights are dim, a resistance problem in the supply wiring or ground wire is usually suspected. When the lights get brighter as the engine accelerates, a charging system is usually the problem. If the lights fail to operate, the bulb(s) may be burned out or a component of the circuit may be defective. Feedback from another electrical component on a circuit that shares common connectors may also interfere with the operation of the parking lights and taillight system.

Directions

Review and use the information found in the Information Sheet, Objective 2, the introduction to Job Sheet 4, Student Supplement 2, Headlight Diagnosis Chart, and Student Supplement 4, *Feedback* to answer the following questions. Write your answer in the blank provided.

____ 1. Technician A says that a brake light switch is defective because the left brake light is not working. Technician B says that both lights would not work if it were a defective brake light switch. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Assignment Sheet 2

____ 2. Which of the following is **not** a possible cause for parking and taillight circuits being dim?

a. resistance in the ground wire
b. resistance in related wiring
c. burned out bulb
d. defective connector points

____ 3. Which of the following is **not** a possible cause for failure of one taillight?

a. burned out bulb
b. defective headlight switch
c. open circuit
d. resistance in the related wiring

____ 4. Which of the following is a possible cause for both taillights **not** working?

a. fusible link
b. defective headlight switch
c. open circuit
d. all of the above

____ 5. Which of the following is **not** a possible cause for lights brighter than normal when the engine is accelerating?

a. defective voltage regulator
b. defective headlight switch
c. defective charging system
d. short in the circuit

____ 6. Both taillights are inoperable. Technician A thinks a defective fusible link or headlight switch may be the cause. Technician B thinks a defective fuse and an open circuit may be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. One burned out taillight can **not** keep the other taillight from burning. True or False?

a. True
b. False

____ 8. The parking lights operate when the headlight switch is in the park position only. True or False?

a. True
b. False

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____ 9. The back-up lights, license-plate lights, brake, parking, rear-turn signals, and rear-hazard lights are all a part of the parking light and taillight circuit on a vehicle with brake lights that fail to work. Technician A says the brake lights are connected directly to the battery and the fuse should be checked. Technician B says that the headlight switch is probably defective. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 10. Which of the following is **not** a possible cause for feedback?

a. blown fuse
b. burned out bulb
c. socket corrosion
c. corrosion on a shared connector

Objective 11

Assignment Sheet 3—Diagnose the Cause of Stoplight (Brake Light) Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 6 of the 8 questions correctly per Answers to Assignment Sheet 3	______

Basic Skills

Reading Critical Thinking

Directions

Review and use the information found in the Information Sheet Objectives 3 and 5, the introduction to Job Sheet 5, and Student Supplement 4, *Feedback* to answer the following questions. Write your answer in the blank provided.

____ 1. When repairing a vehicle with stoplights (brake lights) that do not operate, Technician A says testing the stoplight (brake light) circuits include testing the turn signal and hazard warning light circuits. Technician B says they are different circuits and do not involve the stoplight (brake light) circuit. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. When repairing a vehicle with stoplights (brake lights) that do not operate, Technician A says testing the turn signal switch contact points may be needed. Technician B says the switch does not involve the stoplight (brake light) circuit. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. When repairing a vehicle with stoplights (brake lights) that do not operate, Technician A says a common electrical device like a diode may need to be tested. Technician B says a common electrical device like a STDT switch may need to be tested. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. A cigar lighter fuse is wired on the same circuit as the stoplights (brake lights). Technician A says the stoplights (brake lights) may be dimming due to a blown cigar lighter fuse causing feedback. Technician B says the stoplights (brake lights) are connected directly to the battery and the feedback from the blown cigar lighter fuse would not interfere with the operation of the stoplights. Who is correct?

a. Technician A
b Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. Which of the following is **not** part of a typical stoplight (brake light) circuit.

a. stoplight (brake light) switch
b. fuse
c. ground wire
d. headlight switch

____ 6. Brake pedal movement results in which of the following?

a. closes the stoplight switch
b. supplies voltage to the 7-way connector
c. relays current to the taillight light bulbs
d. all of the above

____ 7. A gear shift switch may be part of the stoplight (brake light) circuit. True or False?

a. True
b. False

____ 8. When testing for failure of one stoplight (brake light), Technician A says that a blown fuse may be the problem. Technician B says the problem is a burned out bulb. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 12

Assignment Sheet 4—Diagnose the Cause of Turn Signals and Hazard Lights Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 4	______

Basic Skills

Reading   Critical Thinking

Directions

Review and use the information found in the Information Sheet, Objective 4, the introduction to Job Sheet 6, and Student Supplement 5, *Turn Signal and Hazard Light Circuit Malfunction Chart* to answer to following questions. Write your answer in the blank provided.

____ 1. Which of the following is not a part of the turn signals and hazard lights circuit?

- a. indicator bulbs
- b. photocell sensor
- c. flasher unit
- d. turn signal switch

____ 2. When testing for failure of all the turn signals and hazard lights, Technician A says that a blown fuse may be the problem. Technician B says the problem is a burned out bulb. Who is correct?

- a. Technician A
- b. Technician B
- c. both Technician A and B
- d. neither Technician A nor B

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____ 3. The flashing unit of the turn signals and hazard lights circuit is a temperature-sensitive bimetallic strip and a heating coil. If the heating coil fails to receive current from the contacts inside the turn signal switch, the flashing unit will fail. True or False?

a. True
b. False

____ 4. Which of the following is the most common cause of one of the turn-signals or hazard lights failing?

a. burned out bulb
b. defective turn signal switch
c. burned out fuse
d. defective ignition switch

____ 5. Technician A says the turn signal switch is defective because it indicated an open circuit. Technician B says the turn signal switch is good when the terminals in the circuit are closed. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. The hazard lights flasher unit fails to operate. Which of the following is the most probable cause?

a. faulty fuse
b. poor ground at bulbs
c. loose or corroded external bulb connection
d. broken canceling finger on switch

____ 7. Technician A says the cause of the system not flashing on one side may be an open circuit in the wiring to an external bulb. Technician B says an open circuit in the flasher unit may be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician.A and B
d. neither Technician A nor B

____ 8. When the turn signal and hazard lights system fail to cancel, mechanical problems should be suspected. True or False?

a. True
b. False

_____ 9. Technician A says the cause of the system not flashing on both sides may be an open circuit in the wiring to an external bulb. Technician B says an open circuit to the flasher unit may be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 10. Technician A says the cause of the system not canceling after completing of the turn may be a broken or loose canceling cam. Technician B says an open circuit to the flasher unit may be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 13

Assignment Sheet 5—Diagnose the Cause of Back-Up Lights Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 5 of the 7 questions correctly per Answers to Assignment Sheet 5	______

Basic Skills

Reading

Critical Thinking

Introduction

Back-up lights may have one or both lights not operating properly. If one light does not operate properly, a burned out bulb or open circuit may be the possible cause. If both lights do not operate properliy, a defective back-up light switch, defective headlight switch, burned out bulbs, burned fuses, open circuit, defective fusible link or defective battery may be the cause.

Directions

Review and use the information found in the Information Sheet, Objective 5, and the introduction to Job Sheet 7 to answer the following questions. Write your answer in the blank provided.

____ 1. Which of the following is **not** a component of the back-up light circuit?

a. ignition switch
b. flasher unit
c. back up light switch
d. battery

____ 2. The back-up lights fail to operate when the transmission lever is shifted into reverse. Technician A says a mechanical problem with the linkage in the gear selector of the transmission is probably the problem. Technician B says a faulty back up lights switch can cause the lights to fail. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. The back-up lights operate when the transmission lever is shifted into drive. Technician A says a mechanical problem with the linkage in the gear selector of the transmission is probably the problem. Technician B says a faulty back-up light switch can cause the lights to come on when the transmission lever is shifted into drive. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. The back-up lights operate when the brakes are applied. Technician A says an open circuit may be the problem. Technician B says the brake switch is defective. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. The back-up lights fail to operate when the transmission lever is shifted into reverse. Technician A says a fusible link may be the problem. Technician B says feedback might be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. The back-up lights fail to operate when the transmission lever is shifted into reverse. Technician A says a turn signal switch may be the problem. Technician B says a blown fuse might be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. One back-up light fails to operate when the transmission lever is shifted into reverse. Technician A says a burned out bulb is probably the problem. Technician B says a blown fuse might be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 14

Assignment Sheet 6—Diagnose the Cause of Instrument Lighting Problems

Name ____________________ Overall Rating __________

Date ____________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 6	______

Basic Skills

Reading

Critical Thinking

Directions

Review and use the information found in the Information Sheet, Objective 6, the introduction to Job Sheet 8, and Student Supplement 4, *Feedback* to answer the following questions. Write your answer in the blank provided.

____ 1. Technician A says that a defective headlight switch is a probable cause for failure of all the instrument panel illumination bulbs. Technician B says the failure of a single illumination bulb can cause all of the bulbs to fail. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. Which of the following is **not** a possible cause for all of the instrument panel lights failing to operate at all?

a. defective fuse
b. defective headlight switch
c. defective connector
d. feedback

____ 3. A client complains that the instrument panel lights do not change intensity when the headlight switch is rotated. Technician A says that a headlight switch has a stripped gear. Technician B says the contact points on the headlight switch, rheostat and/or potentiometer may be worn or defective. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. Which of the following is **not** an instrument lighting circuit component?

a. variable resistors
b. fuse
c. photocell
d. relay

____ 5. Which of the following situations illustrates a condition that may be due to feedback?

a. The instrument lights dim when the headlight switch knob is rotated to increase intensity.
b. The instrument lights dim when the brakes are applied.
c. both A and B
d. neither A nor B

____ 6. Which of the following components is **not** a suspect when an activated cigar lighter causes the map light to dimly light up?

a. a connector
b. short in the headlight bulb socket
c. fuse
d. conductor

____ 7. A client complains that the instrument panel lights flash on and off. Technician A says that a headlight switch is defective. Technician B says worn, damaged, or defective wiring may be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 8. The instrument lighting circuit is receiving very little electrical current. Which of the following conditions might be linked to insufficient voltage?

a. lights are bright
b. lights are dim
c. lights fail to operate
d. none of the above

_____ 9. The rheostat for the instrument lighting circuit may be located by itself on the dash or in the headlight switch. True or False?

a. True
b. False

_____ 10. Technician A says that fiber optic leads are connected to panel illumination bulbs. Technician B says that fiber optic leads are connected to a lens on the instrument panel. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 15

Assignment Sheet 7—Diagnose the Cause of Courtesy Lights Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	_____
• Answered a minimum of 7 of the 9 questions correctly per Answers to Assignment Sheet 7	_____

Basic Skills

Reading

Critical Thinking

Directions

Review and use the information found in the Information Sheet, Objective 7, the introduction to Job Sheet 9, and Student Supplement 4, *Feedback* to answer the following questions. Write your answer in the blank provided. Write your answer in the blank provided.

____ 1. Technician A says that a defective headlight switch is a probable cause for failure of all the courtesy light bulbs. Technician B says that a probable cause is the power supply, possibly the fusible link or battery connection. Who is correct?

a. Technician A
b Technician B
c both Technician A and B
d neither Technician A nor B

____ 2. Technician A has found a short to ground in the door-jam switch. Technician A says this is a possible cause for the dome light and interior courtesy lights staying on when the door is closed. Technician B says that feedback is the problem with the lights staying on when they are not supposed to. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. The courtesy and dome lights come on dimly when the cigar lighter is pushed in. This is an example of which of the following?

a. feedback
b. short to ground
c. battery drain
d. none of the above

4. Name three of the most common problems of the courtesy light circuit.

____

____

____

5. Describe a courtesy lights circuit complaint that is an example of feedback.

____

____

____

____ 6. A client complains that the interior lights do not work when the door is open or when the headlight switch is in the proper position. The bulbs are found to be good as a result of inspecting the bulbs for burned filaments. Technician A says the next step would be to check the power supply for a blown fuse. Technician B says that if the bulbs tested good, feedback is probably the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. A cigar lighter fuse is blown. Technician A says the fuse is probably causing the map light to be dim when the door is open. Technician B says a blown fuse isn't usually involved in feedback problems. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

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____ 8. Technician A says an open in the circuit of the rheostat may cause all of the bulbs to fail to light. Technician B says an open circuit in one bulb may cause all the bulbs to fail. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 9. Instrument panel light bulbs are wired in series to the battery. True or False

a. True
b. False

Objective 16

Job Sheet 1—Inspect, Replace, and Aim Headlights/Bulbs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Mathematics Critical Thinking Employability

Introduction

Headlight Bulbs

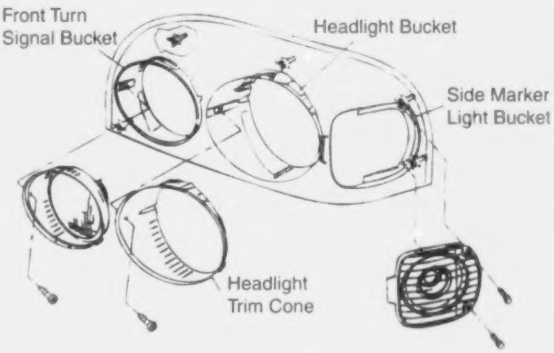
Knowing how to inspect, test, and replace headlights/bulbs will assist the Electrical Systems Technician with all lighting system bulbs and/or repair. Most headlight/bulbs have one or two filaments enclosed in a glass or plastic housing. The filament heats up to an intense white heat when current is passed through it. Because of the intense heat the filament can burn in half. This is usually the problem when headlights bulbs fail.

Some headlight/bulbs use a vacuum and halogen gas inside the glass or plastic housing to increase the life of the bulb. In some vehicles a ballast is used to step up the power of a 16 amp maxi-fuse supplying current to the light bulb. This type of ballast light bulb is called an ION beam light bulb. It provides bulb longevity as well as a truer whiter light. If an ION bulb were to burn out, it is usually replaced with a new headlight assembly.

Some bulbs are easy to get to and some are more difficult. Most headlight units must be disassembled before the bulb may be inspected or replaced. When reassembling a headlight unit it is important to install the headlight lens back to its proper position which is usually marked at the top of the lens.

Job Sheet 1

Figure 1



Courtesy of Freightliner LLC

After taking the headlight unit apart, inspect the bulb for a burned filament. Also inspect the socket and metal contacts of the bulb for corrosion or wear. Clean the socket if it appears corroded. When cleaning the socket disconnect the circuit. This will prevent possible injury and damage to the system. Scrape off the metal contacts with a small screwdriver or wire brush. Compressed air can also be used to blow debris out of the socket.

If the bulb is damaged replace it with the correct type and wattage of bulb. Vehicle bulbs generally come with a standard trade number with specific volts and amperes. They may be either single or double filament bulbs. Refer to the appropriate service manual and a vehicle light bulb replacement chart to determine replacement bulb.

To replace a headlight/bulb always follow these guidelines.

Guidelines

1. When replacing headlights/bulbs always turn off the headlights allowing the bulb to cool before touching.

   Note: Current passing through the light bulb heats the filament inside the glass or plastic housing to produce an incandescence light. The filament gets very hot and produces an intense white heat. It is important to let the bulb cool before handling it.

2. When handling the bulb always hold it by the base taking care not to drop or scratch it. Holding the bulb by its base will eliminate the possibility of oil residue from your hands getting on the bulb and causing failure of the bulb.

   Note: Many vehicle bulbs seal out air by removing it. This slows the oxidation between the air and the wire and extends the bulb's life by keeping the filament from burning itself into two pieces. The glass or plastic housing around the filament must keep its integrity in order to maintain the vacuum. Any damage to the glass or plastic housing may shorten the life of the bulb.

3. Keep moisture away from the bulb and socket of the headlight.

In high wattage bulbs particles of tungsten can be burned off the filament even though the air is removed. Inert ingredients are sometimes added to the glass enclosure to slow this process down. Most headlight bulbs in today's vehicles are equipped with quartz halogen lamps. These halogen bulbs are housed in a harder glass shell made of quartz. A halogen bulb differs from a regular bulb because halogen gas has been used to fill the glass or plastic shell. The halogen gas keeps the burned-off tungsten in suspension until it can bind back with the filament. This action prolongs the life of the bulb and produces a more intense heat.

Headlight adjustment

Government regulations set the headlight beam intensity for correct headlight alignment by regulating the height of the low-beam bulb(s). Many of today's vehicle's high-beam bulbs are considered non-adjustable. However, some older vehicles may recommend aligning the high-beam bulb.

Many of today's vehicle manufacturers recommend using a headlight screen to test for proper alignment of the headlights. Older vehicle's service manuals may recommended measuring headlight alignment with mechanical headlight aimers. Other vehicle's service manuals recommend a photoelectric aimer to assist the technician when aiming headlights.

Adjustment screws on a headlight allow the technician to adjust the light pattern by tilting the headlight up or down with one screw or from side to side with another. Headlight adjustment specifications are provided on each headlight unit. Before adjusting the screws, always follow these guidelines to prepare the vehicle for testing and adjustment.

Guidelines

1. Place the vehicle on a level floor with the headlights aimed at the screen located 25 feet away.
2. Rock the vehicle from side to side and front to back to allow the springs to come to rest.
3. Check with the vehicle's service manual to determine whether or not the fuel tank should be half full or full.
4. Inflate the tires to the recommended pressure.
5. Seat a person in the driver's seat.

Warning: Follow all general safety rules for dealing with electrical circuits.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

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Job Sheet 1

Tools, equipment, and materials

- Appropriate service manual
- Technician's common hand tools
- Job ticket—one is included or use appropriate one provided at your facility
- Shop towel
- Wheel chocks
- Safety glasses
- Student Supplement 1

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Sealed beam bulb replacement

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Remove the cover that fits around the bulb by removing headlight ring screws and trim ring screws. Take care not to turn or remove the headlight adjustments screws.

Note: Some headlight units may have springs holding the ring. Unhook springs.

☐ 6. Remove the bulb using the guidelines from the introduction.

Note: When unplugging bulb, be careful not to pull too hard on the wires; damage may result to the connector.

☐ 7. Install the correct replacement bulb by aligning the prongs on the bulb with its connector. Push the prongs into the connector. Make sure the bulb fits, securing into the notches in the shell.

☐ 8. Replace headlight ring and screws.

Procedure

Halogen insert bulb replacement

Warning: Halogen light is extremely hot, allow bulb to cool before touching. Touching may result in injury to skin or clothing.

1106

☐ 1. Remove the insert bulb from the rear of its plastic or glass housing.

Note: Access to the insert bulb is generally through the body of the vehicle.

☐ 2. Install the correct replacement bulb by aligning the prongs on the bulb with its connector.

Note: Be sure to avoid moisture or oil from hands from touching the bulb. Use a clean shop towel to hold the bulb.

Procedure

Headlight adjustment using aiming screen

☐ 1. Use the guidelines above to prepare the vehicle for testing.

☐ 2. Prepare the aiming screen by marking it with tape.

☐ 3. Determine vehicle centerline by placing two small pieces of tape at the center of the windshield and the rear window. Place a length of tape vertically on the screen slightly above your line of sight above the pieces of tape on the windows.

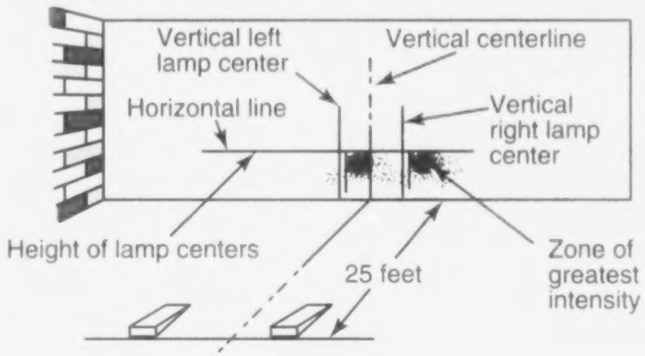
☐ 4. Measure the height of the headlights from the floor and place a piece of tape horizontally on the screen at the same height from the floor.

☐ 5. Measure the distance between the centerline of the vehicle and each headlight. Place vertical lengths of tape at the same distance as the headlights are from the centerline of the vehicle on the screen.

Note: If the vehicle has a two or four headlight system, tape a vertical length of tape on the screen where the additional headlights measure from the centerline of the vehicle. In other words, a two headlight system would require two additional vertical lengths of tape on the screen.

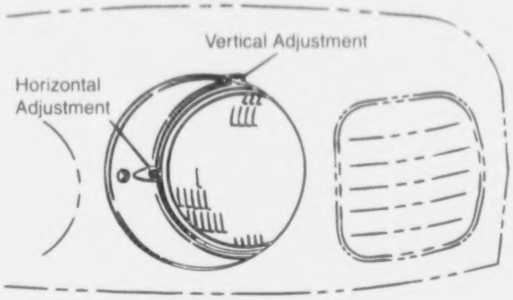
☐ 6. Turn on the headlights. Observe the pattern on the screen.

FIGURE 2


Vertical left lamp center
Vertical centerline
Horizontal line
Vertical right lamp center
Height of lamp centers
25 feet
Zone of greatest intensity

☐ 7. Adjust one or both headlights to produce proper pattern of light by using the vertical and horizontal adjustment screws.

Figure 3



Courtesy of Freightliner LLC

Note: Adjust the headlights following the appropriate service manual specifications or state vehicle inspection laws. State inspection regulations take precedent over manufacturer's recommendations.

Procedure

Headlight adjustment using mechanical headlight aimer or photoelectric aimer.

☐ 1. Use the aiming instructions provided with the mechanical headlight aimer or photoelectric aimer.

☐ 2. Turn in job ticket when finished.

☐ 3. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

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Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 17

Job Sheet 2—Inspect, Test, and Replace Light Bulbs and Test Sockets

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Follow safety rules throughout procedure	______
• Followed correct procedure for exposing and inspecting bulb	______
• Obtained proper replacement bulb as necessary	______
• Followed correct procedure for testing socket	______
• Followed correct procedure for installing bulb and socket	______
• Cleaned work area and properly stored equipement and materials	______

Basic Skills

Reading Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Light bulb pliers
- Diesel lighting circuit
- Screwdriver
- Safety glasses
- Socket-cleaning brush
- Student Supplements 1 and 2

Note: Procedures may vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

Inspect, test, and replace light bulbs

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in “neutral”; if it has an automatic transmission, place it in “park” or “neutral”.

Note: Some vehicles with automatic transmissions do not have “park”.

☐ 5. Make sure switch that operates bulb is turned off.

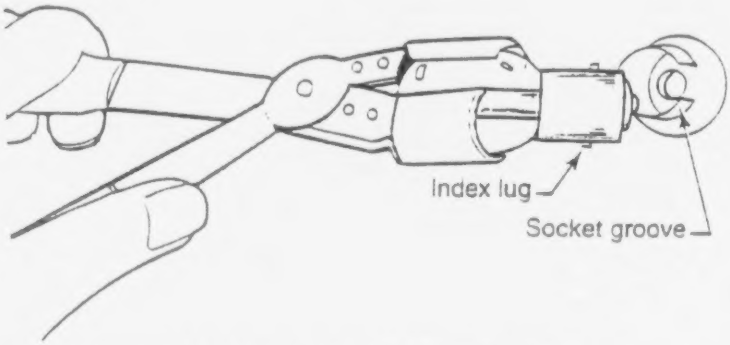
Warning: The switch must be turned off to prevent a short while you expose the bulb and clean the light socket.

☐ 6. Expose the bulb for inspection. Check service manual to determine proper method of exposing bulb for removal from its socket.

☐ 7. Remove exposed bulb from socket: Using light-bulb pliers, turn bulb about 1/4 turn to unlock index lugs from socket groove, then pull bulb straight out of socket.

Warning: Do not use your fingers to remove a bulb from its socket. Use light-bulb pliers to protect your fingers should the bulb breakduring removal.

Figure 1



Adapted with permission of the State of Florida, Department of State

☐ 8. Inspect bulb:

  a. For signs of corrosion on bulb base. If base is corroded, clean with sandpaper.

  b. For signs that glass is loose from bulb base. If so, check service manual and obtain proper replacement bulb.

☐ 9. If original bulb does not appear defective, test light bulb with ohmmeter or ohmmeter function of multimeter.

☐ 10. If original bulb tests defective, check service manual for proper replacement bulb and obtain.

☐ 11. Inspect socket housing for signs of corrosion, and clean socket with socket-cleaning brush if necessary.

☐ 12. Insert replacement bulb or original bulb into light socket, making sure bulb index lugs fit into socket grooves properly.

Note: If the index lugs are offset, one groove in the socket will be deeper than the other. This lets you know you have installed the wrong bulb.

☐ 13. Turn on switch that operates bulb to test that bulb will now light.

☐ 14. If bulb does light, turn off switch to light and restore bulb and socket to proper condition.

☐ 15. If bulb does not light, test socket to determine whether or not current is getting to socket.

Procedure

Test a single-terminal light socket (back-up lights, side-marker lights)

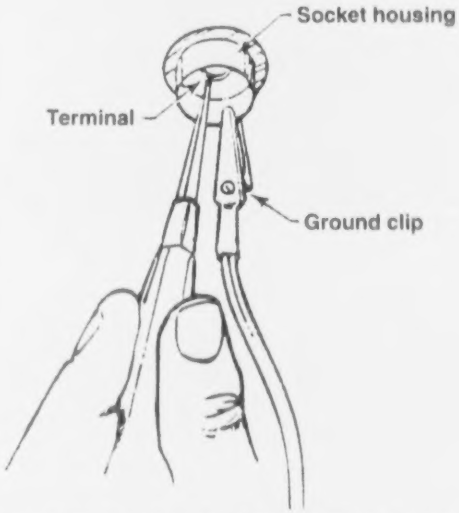
☐ 1. Remove bulb from socket.

☐ 2. Clip ground clip of 12-volt test light to socket housing or other good ground.

☐ 3. Touch sharp point of test-light probe to light-socket terminal (Figure 2).

> Caution: Do not allow test-light probe to contact socket housing. This could cause a short that would blow fuses in the circuit.

Figure 2



Adapted with permission of the State of Florida, Department of State

☐ 4. Record test results: If test light does not light up, electrical current is not present at socket; if test light does light up, electrical current is present at socket.

☐ 5. Notify instructor of test results.

☐ 6. Install bulb and socket in vehicle. Check service manual for proper method of installing bulb and socket.

☐ 7. Clean work area and return equipment and materials to proper storage.

Procedure

Test a dual-terminal light socket (stop lights, taillights, front parking lights, turn signal lights)

☐ 1. Remove bulb from socket.

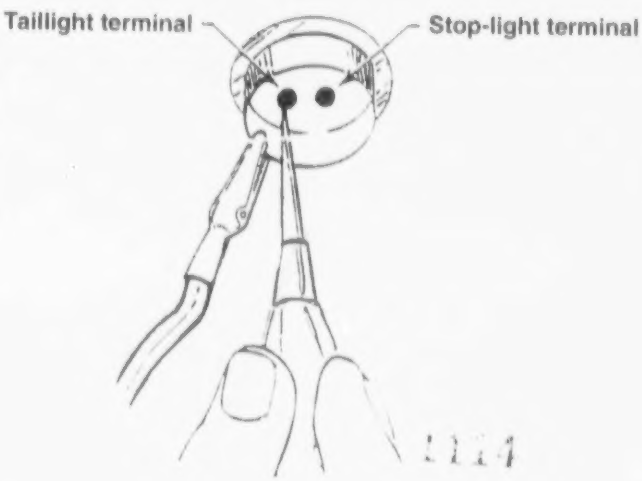
☐ 2. Clip ground clip of 12-volt test light to socket housing or other good ground.

☐ 3. Check vehicle wiring diagram to determine which terminal should be tested.

☐ 4. Touch sharp point of test-light probe to correct light-socket terminal (Figure 3).

> Warning: Do not allow test-light probe to contact socket housing. This could cause a short that would blow fuses in the circuit.

Figure 3



☐ 5. Record test results: If test light does not light up, electrical current is not present at socket; if test light does light up, electrical current is present at socket.

☐ 6. Notify instructor of test results.

☐ 7. Install bulb and socket in vehicle. Check service manual to determine proper method of installing bulb and socket.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return equipment and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 3—Inspect, Test, Repair, and Replace the Components of a Headlights and Daytime Running Lights Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Apart from the required safety inspection each year, headlights need to be inspected when a client complains that the headlights fail to work, work improperly, or when the headlights need adjusting. Inspection and service of the headlights primarily include inspection of headlights on bright and dim, bulb replacement, aiming of the low beam, and testing for wiring-related problems. Complaints of the headlight system include burned-out bulbs, lights dimming, lights flickering, and/or failure to operate.

When servicing the headlight circuit visualize the complete circuit and follow the path of the current. Use logical thinking to direct you through the entire path of the circuit. More often than not, this mental exercise will save time and energy by helping you determine the most probable cause. Use basic testing methods you have learned in previous units on circuit and battery repair to find the source and location of power failure. For example, you have learned how to identify areas of high resistance in the circuit by using a voltage drop test to help determine where the short is located in a circuit. Look at the wiring diagram, component locator, and appropriate service manual for help in locating circuit problems.

Headlights are self-contained units consisting of bulb(s) in glass or plastic housing. The filament within the bulb heats up to an intense white heat when current is passed through it. A reflective backing in the unit reflects the light of the burning filament. An outer prism lens redirects the light beam to provide a larger path of the incandescent light.

Look at the headlight circuit in the Information Sheet and follow the current from the battery as it moves through its various components. Notice how current is wired from the battery to the headlight bulbs parallel to each other. This means each headlight is independent of one another. By being independent of one another a total failure of the system is prevented when one headlight is not operating properly.

After visualizing the circuit select the most probable component causing the problem and start with it.

The headlights are connected directly to the battery through the headlight switch. The headlight switch may be a single switch or a part of a multi-function switch located on the steering column of the vehicle. An open or shorted circuit in a bad headlight switch may prevent the headlights from operating. The contacts in the switch can burn and develop high resistance or short out. Defective contacts are usually the cause of a defective headlight switch.

In some vehicles an automated on/off headlight system senses incoming light equivalents. A photocell, usually located in the dash, and an amplifier trigger the sensor amplifier module that energizes the relay, turning on the headlights and exterior parking lights.

In addition to an automatic on/off headlight switch, some vehicles are equipped with a photocell usually located in the grill of the vehicle that senses oncoming light (automatic dimmer). This photocell sensor activates much in the same way as the automatic on/off headlight switch. It uses an amplifier to energize a relay that will dim the headlights when light levels increase and activate the high beam of the headlights when light levels decrease. Always refer to appropriate service manual for make and model of vehicle as equipped. Check the regular head-light system first before suspecting the automatic headlight system.

Start inspecting the headlight unit by turning the headlight switch to the headlight position and placing the dimmer switch on low beam. This action opens the path of the circuit that provides current to the low-beam filaments of the headlights. Check to see if both headlights are operating properly. Flip the dimmer switch to the high beam. This allows current to pass through the high-beam filaments. Check for light. If a bulb appears burned out, replace the bulb.

If both headlights are flickering or dimming, there is probably a problem with a weak or damaged battery, loose connection, corroded plugs or sockets, circuit breaker turning on and off, headlight switch, or related wiring problems. Try to find out if the lights flicker only in some circumstances. For instance, only when road shock happens or when the dimmer is in the low-beam position. If both bulbs are out check the battery, fusible link, circuit breaker, relay and/or wiring. Test for power loss using a test light or DVOM.

If one of the headlights is flickering or dimming there is probably a short in the circuit. Start your inspection at or near the bulb of the headlight unit. Visually inspect the socket connections for corrosion. Make sure the wiring is connected properly and in good condition. Replace or clean the socket and wiring as needed. Replace bulbs as needed. Continue to inspect the wiring along the path of the circuit. A defective headlight switch or insufficient voltage may also be the problem.

Job Sheet 3

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- DVOM
- Student Supplements 2, 3, and 4
- Shop towel
- Test light
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagou;procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 19

Job Sheet 4—Inspect, Test, Repair, and Replace the Components of a Parking Light, Clearance Light, and Taillight Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Science Critical Thinking Employability

Introduction

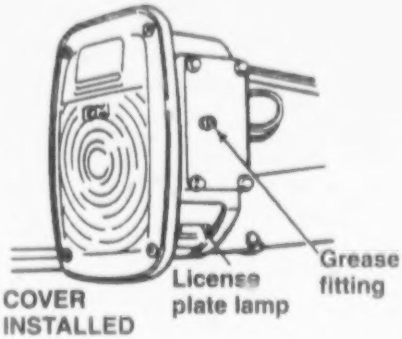
Apart from the required safety inspection each year, inspecting and testing components of a parking light, clearance light, and taillight circuit is required when the lights dim, are brighter than normal, or fail to operate. When the lights dim, a resistance problem in the wiring or ground wire is usually suspected. When the lights get brighter as the engine is accelerated, a charging system and/or defective voltage regulator is usually suspected as producing higher voltage than specified. If the system fails to operate completely, the bulb(s) may be burned out or a headlight switch could be defective. Use basic testing methods you have learned in previous units on circuit and battery repair to find the source and location of power failure or the malfunction.

Depending upon vehicle design the back-up lights, license-plate lights, brake, parking, rear turn signals, and rear hazard lights may also be a part of the parking light and taillight circuit. These additional lights and switches may be added to the parking, clearance, and taillight circuit through relays, connectors, bulbs, and direct wiring. Additional controlling switches for these additional lights are connected to the battery in series. For instance, the brake light switch is connected directly to the battery usually through a fuse. This independent circuit is always "hot". When the brakes are applied, the pedal-arm pin and pushrod of the brake pedal move to close the contact points of the taillight switch. When the points are closed the light bulbs have current and produce incandescent light. These bulbs are connected directly to the parking lights circuit.

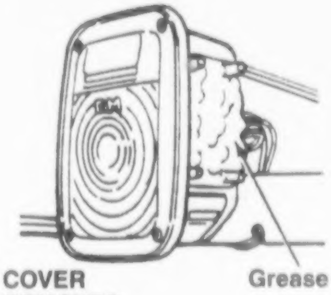
Like in the headlight circuit, the headlight switch controls current flow to the parking, clearance, and taillight system. When the headlight switch is turned to the park and/or on position, current flows from this switch to the taillight bulbs and side marker bulbs. Using basic testing, repair, and/or replacement methods you have learned in previous job sheets, test the headlight switch and bulbs.

After taking the taillight unit apart inspect the bulb for a burned filament.

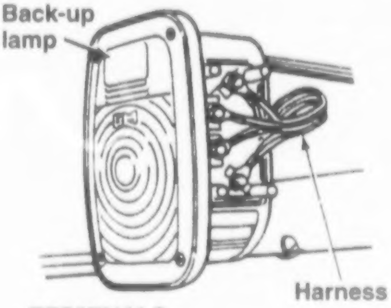
Figure 1


License plate lamp
Grease fitting

COVER INSTALLED



COVER REMOVED


Back-up lamp
Harness

TERMINALS INSTALLED

Note: Many rear light bulbs are a combination bulb containing stop and taillight filaments. Some circuits are two bulb circuits and some are three bulb circuits. For instance, on a three-bulb circuit the taillight, parking lights, and turn signal may share one bulb. The bulb may be a single filament or dual filament bulb.

Also inspect the socket and metal contacts of the bulb for corrosion or wear. Clean the socket if it appears corroded. When cleaning the socket disconnect the circuit. This will prevent possible injury and damage to the system. Scrape off the metal contacts with a small screwdriver or wire brush. Compressed air can also be used to blow debris out of the socket. If the bulb is damaged replace it with the correct type and wattage of bulb. Refer to appropriate service manual and vehicle light bulb replacement chart to determine correct replacement. Use methods you have learned in previous job sheets to inspect, test, and replace bulbs.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility.
- Wheel chocks
- Safety glasses
- Student Supplements 3 and 4

Note: Procedures vary with the vehicle. Always check the procedures in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

Objective 20

Job Sheet 5—Inspect, Test, Adjust, Repair, and Replace the Components of a Stoplight (Brake Light) Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Apart from the required safety inspection each year, inspecting and testing components of a stoplight (brake light) circuit is required when the lights dim, are brighter than normal, or fail to operate. The wiring should be inspected for corrosion, wear, and/or damage whenever the hood is open. Components of the stoplight (brake light) circuit include fuses, fusible link, wiring, stoplight (brake light) switch, bulbs, and ground wire. Other components of the stoplight (brake light) may include back-up light bulbs, turn signal and hazard switches, and gear shift or transmission switches. When inspecting and testing the components of a stoplight (brake light) circuit, use some of the same methods and logic used in inspecting, testing, and repair/replacing components of other lighting circuits.

In many of today's vehicles the stoplight (brake light) bulb filaments are usually mounted in the same bulb as the turn signal and hazard warning light bulbs. A bulb in the taillights will have two filaments that perform more than one function. The stoplight (brake light) uses a high-intensity filament of a two filament taillight. In vehicles that use dual filament bulbs the stoplight (brake light) may be wired through the turn signal and hazard switch. Worn or damaged contacts in the turn signal and hazard light switches may also produce stoplight failure or improper operation. In vehicles where the stoplight (brake light) uses more than one bulb, the stoplight (brake light) circuit is usually connected directly to the battery through a fuse and the brake-light switch. This means the ignition switch does not need to be on for the brake-light switch to work.

The stoplight (brake-light) switch is an insulated switch used to relay current to the stoplight (brake light) bulbs. The stoplight (brake light) bulbs have a ground wire to complete the circuit. The stoplight (brake-light) switch is a pressure-sensitive switch attached to the brake pedal, or on heavy vehicles employing air brakes, one or two switches are located in the air brake system. Worn contacts in the stoplight (brake-light) switch can prevent the stoplight (brake light) from receiving the right amount of current. A 12V test light will quickly tell if the stoplight (brake-light) switch is malfunctioning.

If one stoplight (brake light) fails to operate, inspect, test and/or replace the light bulb. If the light bulb tests good or if the replacement bulb fails to operate, check the stoplight (brake light) switch. If both stoplights (brake lights) fail to operate, check the stoplight (brake light) fuse, and replace it if defective. If the fuse is blown, check for a short circuit and repair it when located. To test for a defective stoplight (brake light) switch bypass the brake-light switch. If the circuit is wired through the turn signal and hazard switch leave it in neutral operation. If the lights operate, a defective brake-light switch is the problem.

Always refer to appropriate service manual for correct procedures when repairing or replacing components of the stoplight (brake-light) circuit.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Student Supplements 3 and 4

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made:	LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 21

Job Sheet 6—Inspect, Test, Repair, and Replace the Components of a Turn Signal and Hazard Lights Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

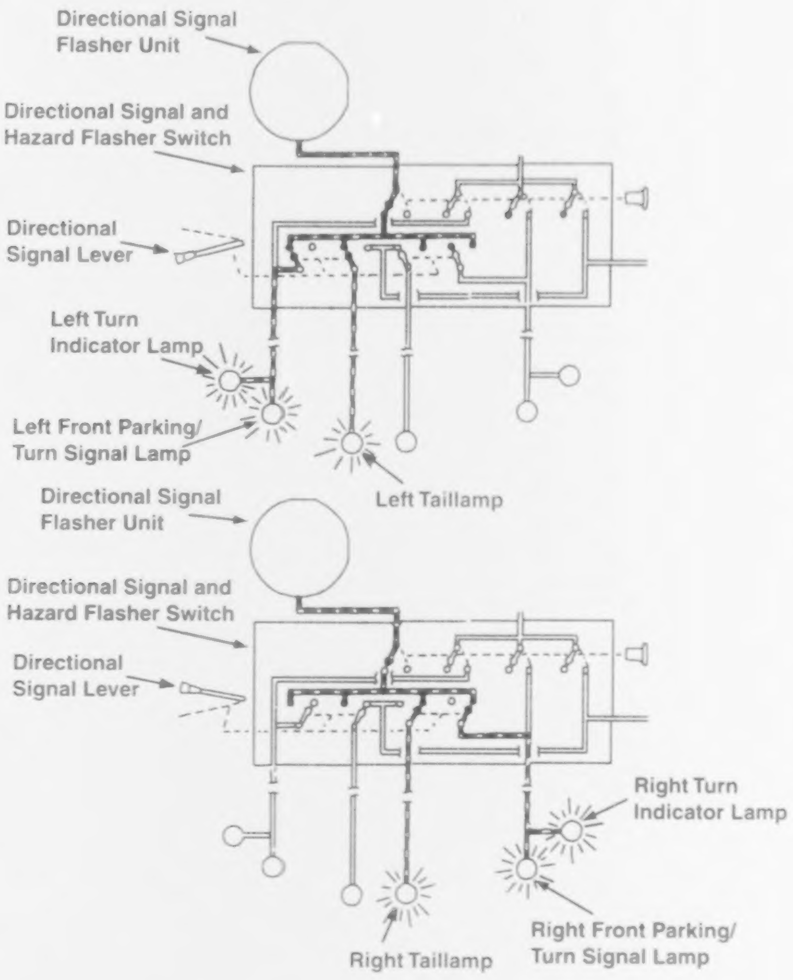
Reading Science Critical Thinking Employability

Introduction

Apart from the required safety inspection each year, inspecting and testing components of a turn signal and hazard lights circuit is required when the lights fail to operate or operate improperly. Components of the turn signal and hazard lights include flasher unit, turn signal light bulbs, fuse, indicator bulbs, turn signal switch, wiring harnesses, and related wiring. Current flows from the flasher unit to the turn signal switch and then the grounded light bulbs of the circuit as directed by the turn signal switch. The most common cause of the turn-signal and hazard light circuit is a burned out bulb. Because the light bulbs are wired in series to each other, if one light bulb burns out it could prevent the flasher unit from working. If both signal lights fail to operate, using logic will indicate that something common to both sides of the circuit is probably at fault like the fuse and/or flasher unit.

When the turn signal is in a neutral position the contacts of the turn signal switch open, preventing current flow to either side of the vehicle. When the turn signal is in left-turn position, the turn signal switch closes the contacts, allowing current to flow to the front and rear lights on the left side of the vehicle. When the turn signal is in right-turn position, the turn signal switch closes the contacts, allowing current to flow to the front and rear lights on the right side of the vehicle.

Figure 1


Directional Signal Flasher Unit
Directional Signal and Hazard Flasher Switch
Directional Signal Lever
Left Turn Indicator Lamp
Left Front Parking/ Turn Signal Lamp
Left Taillamp
Directional Signal Flasher Unit
Directional Signal and Hazard Flasher Switch
Directional Signal Lever
Right Turn Indicator Lamp
Right Taillamp
Right Front Parking/ Turn Signal Lamp

The turn signal switch may be part of a combination switch with the headlight, washer-wiper, and other switches or it may be by itself. Some vehicles have a late-change directional signal switch that allows the driver to hold down on the turn signal light switch lever to signal a lane change. When the driver releases the lever the signal is canceled immediately.

The combination switch is usually found on or in the steering column behind the lock and horn plates. Older vehicles may have the turn signal mounted by itself under the steering wheel. Because combination switches are a little more complex than single switches, diagnosing problems may be more difficult. Refer to the appropriate service manual for a wiring diagram or a pictorial drawing showing the function of combination switches.

If the turn signal switch is defective, it is usually an open or shorted circuit on one or both sides of the turn signal circuit. Inspecting and testing the components of a turn signal and hazard lights circuit use some of the same methods and logic used in inspecting, testing, and repair/replacing components of other lighting circuits. A short or open circuit can be tested by using basic electrical device testing methods. Test or replace a turn signal switch by removing the steering column cover. In older models a wheel puller may be needed to remove the steering wheel in order to test or replace the switch.

The flasher is an important part of the turn signal and hazard lights circuit. If both lights fail to flash the flasher unit may be defective. The flasher unit uses a bimetallic strip and heating coil to open and close the contacts to the turn signal switch and lights and is wired in series to the turn-signal switch. If a light bulb filament burns out the resistance caused by the failed bulb may cause the flasher unit to fail from lack of proper amperes. Use the same methods used in inspecting, testing, and repair/replacing light bulbs from other lighting circuits. When replacing the flasher unit be sure to select the correct flasher unit. An incorrect flasher unit may result in fast, slow, or system failure. Look at the wiring diagram, component locator, and appropriate service manual for help in locating flasher units and specifications.

The hazard lights circuit is part of the turn-signals light circuit. However it differs in the way it is wired to the battery and the amount of current it is able to deliver to all four turn signals and the trailer lights. The flasher unit is usually wired directly to the battery for operation when the ignition switch fails or is in the off position. The hazard flasher unit may be part of the turn signal flasher unit or it may be separate.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Student Supplements 4 and 5

Note: Procedures vary with the vehicle. Always check the procedures in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

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Job Sheet 6

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____

Address ____

Phone # ____

Date In ____

Date Out ____

JOB TICKET

Customer Name ____

Customer Address ____

Customer Phone # ____

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____

Services/repairs made: ____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____ Date ____

Technician ____

Supervisor ____

Objective 22

Job Sheet 7—Inspect, Test, Repair, and Replace the Components of a Back-Up Lights Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Apart from the required safety inspection each year, inspecting and testing components of a back-up light circuit is required when the lights fail to operate or operate improperly. Components of a back-up light circuit include back-up light bulbs, back-up light switch, fuse, gear shift or transmission switch, wiring harnesses, and wiring. Inspecting and testing the components of a back-up light circuit use some of the same methods and logic used in inspecting, testing, and repair/replacing components of other lighting circuits. Test common electrical problems using basic electrical device testing methods. Look at the wiring diagram, component locator, and appropriate service manual for help in locating components of a back-up light circuit.

Current flows from the battery to the ignition switch and back-up light switch. The back-up light switch is moved into an open or closed position by the linkage in the gear selector of the transmission. It may be mounted on the transmission or the steering wheel. Depending upon the position of the gear selector, the current then flows to the grounded back-up light bulbs, producing light. Checking for mechanical problems includes checking the linkage in the gear selector of the transmission to make sure there is nothing binding or the gears are not stripped. Sometimes a back-up light switch can be adjusted to correct the lights coming on when the vehicle is in a forward gear.

Always refer to appropriate service manual for correct procedures when repairing or replacing components of a back-up light circuit.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 7

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual.
- Job ticket—one is included or use appropriate one provided at your facilty.
- Wheel chocks
- Safety glasses
- Student Supplement 4

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 7

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________________

Supervisor ____________________

Objective 23

Job Sheet 8—Inspect, Test, Repair, and Replace the Components of an Instrument Lighting Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Science Critical Thinking Employability

Introduction

When a client complains of no instrument lights, brighter or dimmer than normal lights, or flashing lights, the technician inspects and tests components of an instrument lighting circuit for electrical failure. Instrument lighting circuits components include printed circuits, fiber optics, headlight switch, rheostat and potentiometers. Use the information you have learned in previous units and job sheets on circuits, batteries, bulb replacement/repair, and/or other lighting circuits to test common electrical components of the instrument lighting circuit.

Start by visualizing the circuit. Use the basics you have learned in previous units to think about the most logical cause of the client's complaint. Follow the circuit through the contacts in the headlight switch, variable resistors, printed circuit board, panel illumination bulbs, and fiber optic conductors. Use logical thinking to direct you through the entire path of the circuit. Look at the wiring diagram, component locator, and appropriate service manual for help in locating circuit components and problems.

If all of the instrument lights do not operate, check the battery, fusible link, fuses, and headlight switch for defect, damage or wear. When the fuse is located for the headlight switch, test the headlight switch with a 12 V test light or DVOM while the headlight switch is in the on position. If the fuse is good, continue testing the headlight switch as described in Job Sheet 3. If the headlight switch is good, check the rheostat for worn contact points and printed circuit board for short circuits. If any component is found defective, replace it.

To test the operation of the instrument panel lighting circuit when the lights do not dim or do not brighten, put the headlight switch in the park position and then in the on position. Rotate the headlight switch knob at each position. The instrument panel lights should decrease in brightness when the knob is rotated. If they do not, a stripped gear in the knob or a defective variable resistor is the most likely problem.

If some of the instrument light bulbs operate and some do not, check for a burned out panel illumination bulb. The panel illumination bulbs operate independently from one another and are connected in parallel to the battery. If a bulb is burned out, the others continue to work. If bulbs are burned out replace using procedures and guidelines from previous objectives. If the panel illumination bulb is good, then fiber optic failure may cause the bulb not to operate. Fiber optic failure is usually due to damaged, worn, or severed fiber optic conductors and/or connections.

If the instrument lights are intermittent, check for a short in the wiring or a defective headlight switch. If the instrument lights are dimly lit check for feedback from another circuit. To check for feedback, look for wear, damage, or corrosion on a connector or conductor in the circuit. If the instrument lights are bright, consider a damaged headlight switch, defective rheostat, or insufficient voltage to be the problem.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual.
- Job ticket—one is included or use appropriate one provided at your facilty.
- Wheel chocks
- Safety glasses
- Student Supplement 4

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 24

Job Sheet 9—Inspect, Test, Repair, and Replace Components of a Courtesy Lights Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safe procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

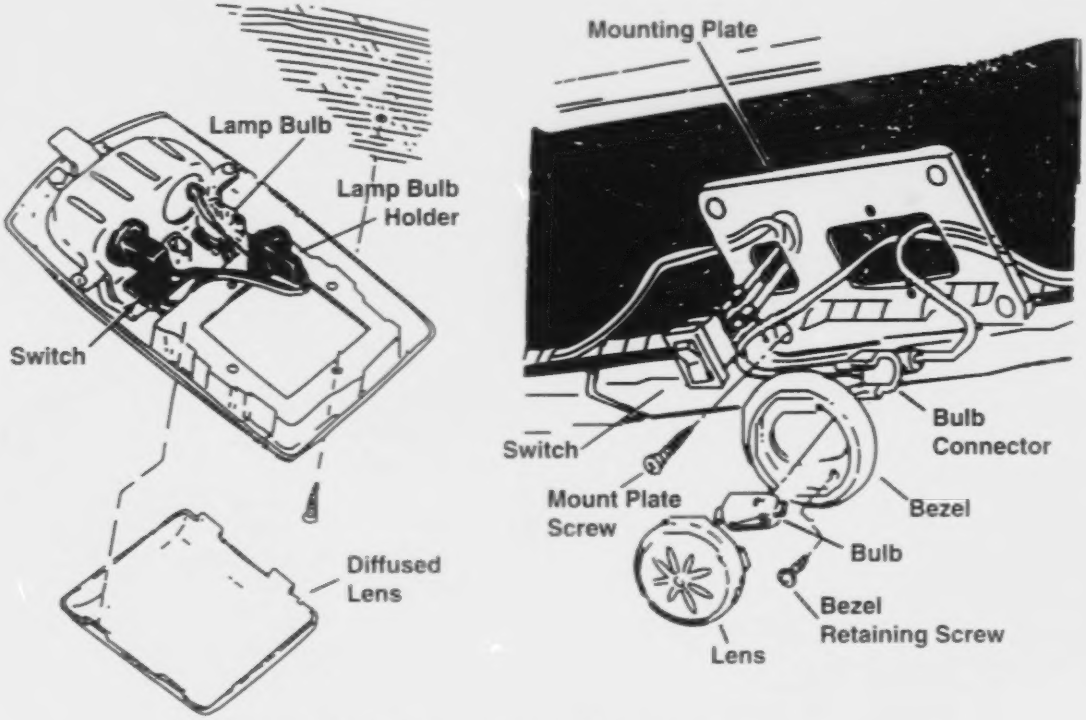
Introduction

Inspecting and testing components of a courtesy lights circuit is required when the lights dim, are brighter than normal, operate intermittently, fail to operate properly, or fail to operate. The wiring should be inspected for corrosion, wear, and/or damage whenever the hood is open.

Components of a courtesy lights circuit include cigar lighter, connectors, door-jam switches, baggage compartment bulbs, ground switch, headlight switch, left and right courtesy lights, reading/map light, and wiring harnesses. Burned fuses, faulty circuit breakers, burned-out bulbs, and feedback are common problems with a courtesy lights circuit. However, feedback is the most common complaint of the courtesy lights circuit. Mechanical problems include jammed pressure-sensitive switches, broken switch levers, and broken lens. Use the information you have learned in previous units and job sheets on circuits, batteries, bulb replacement/repair, and/or other lighting circuits to test common electrical components like fuses, bulbs, wiring, and connections. Look at the wiring diagram, component locator, and appropriate service manual for help in locating circuit components and problems.

The courtesy light circuit uses separate switches to operate the interior courtesy lights, baggage compartment light, dome light, and map light bulb. These switches are either ground switches or insulated switches. Ground circuit switches control the grounding section of the circuit. Insulated switches are used to relay the current to the light bulbs. On some vehicles, interior lights can be controlled by either a separate rocker switch located on the instrument panel, or the headlamp switch where rotation of the switch control knob will result in power being fed to the interior lights. Other vehicles may have a center light which is controlled by door-jam switches, and map lights controlled by switches in each end of the interior or by switches located on the console. Some courtesy lights may be activated by the headlight switch or door-jam switch. Some courtesy lights may be wired in series while some may be wired parallel to each other. For example, the door-jam switch is a pressure-sensitive, ground-circuit, SPST, series-wired switch that completes the current's path to ground for the dome light, door lights, and floor lights when closed. Look at the wiring diagram to determine what type of switch and interconnections they may have.

Figure 1



Courtesy of GMC Truck Division, General Motors Corporation

Start to diagnose the problem of the courtesy lights circuit by visualizing it. Use the basics you have learned in previous units to think about the most logical cause of the client's complaint. Follow the circuit through the contacts in the headlight switch, door-jam switch, relays, and sockets. Use logical thinking to direct you through the entire path of the circuit. Look at the wiring diagram, component locator, and appropriate service manual for help in locating circuit components and problems. Look at the Supplement on feedback to help determine problems when the courtesy lights operate when they are not supposed to. Always refer to appropriate service manual for correct procedures when repairing or replacing components of the courtesy lights circuit.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel clocks
- Safety glasses
- Student Supplement 4

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

Objective 25

Job Sheet 10—Inspect, Test, Repair and Replace the Components of Tractor-to-Trailer Lights Circuits

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Apart from the required safety inspection each year, inspecting and testing components of a trailer lighting circuit is required when the lights dim, are brighter than normal, or fail to operate. When the lights dim, a resistance problem in the wiring or ground wire is usually suspected. When the lights get brighter as the engine is accelerated, a charging system and/or defective votage regulator is usually suspected as producing higher voltage than specificed. If the system fails to operate completely, the bulb(s) may be burned out or a switch could be defective. Use basic testing methods you have learned in previous units on circuit and battery repair to find the source and location of power failure or the malfunction.

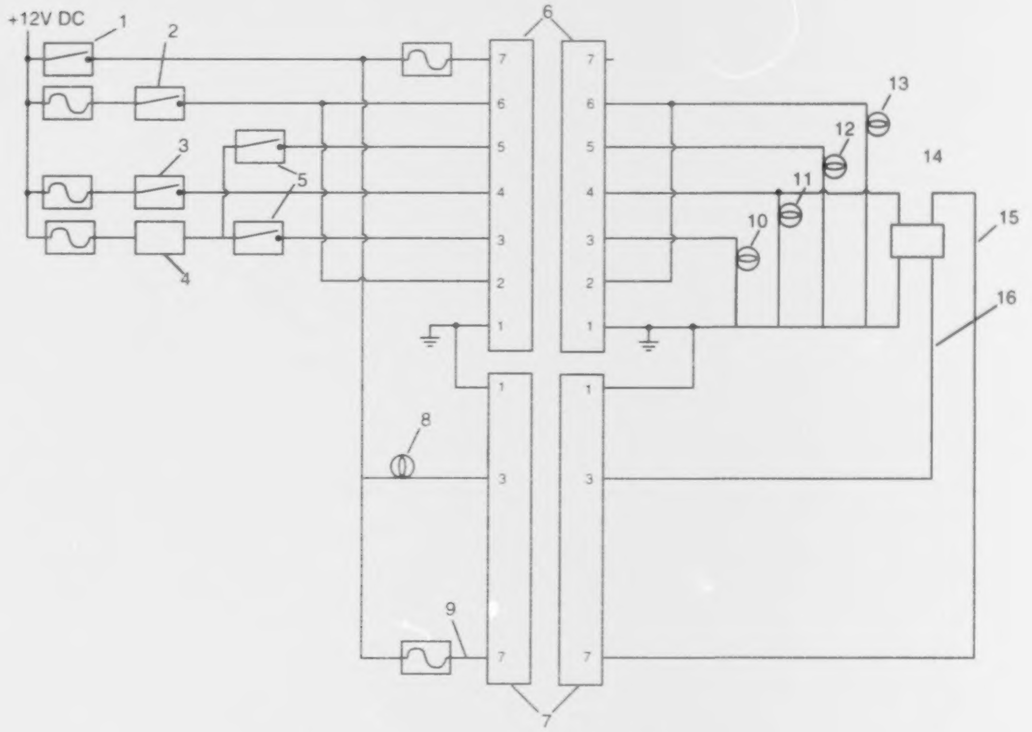
Most trailer wiring is multiple strand copper wire covered with polyvinylchloride (PVC) insulation. Factors that determine wire size are the amp load and required length of wire. The Maintenance Council (TMC) of the American Trucking Association recommends electrical wire in trailers should never be less than 18 gauge.

Recently, plug-in connectors have become popular because of their ease-of-use. These connectors, with seven pins, are standard in the trucking industry. Trailer wiring harnesses using this type of connector often come in sections. Sections can be coupled together, or to lights, to complete the lighting circuit. Most light fixtures are protected where the harness attaches to the fixtures with rubber or plastic.

Note: Never use electrical tape as an insulator where the harness connects to the fixture.

Like in the headlight circuit, the headlight switch controls current flow to the clearance, marker, identification, license and tail lights. Brake lights are controlled through the tractor brakes circuit, and turn signals and hazard lights through the tractor turn signal and hazard lights circuit. If tractor and trailer lights are not working, troubleshoot at the tractor as in previous job sheets. If tractor lights work and trailer lights do not, begin troubleshooting at the junction box and proceed to the seven-pin plug and receptacle. Test the seven-pin plug and receptacle with a DVOM. If circuits are complete to the seven-pin plug, troubleshoot from the seven-pin receptacle to the malfunctioning light.

Figure 1—Dual Connectors on Tractor Dual Connectors on Trailer



1. Ignition Switch
2. Lights Switch
3. Brake Switch
4. Flasher Unit
5. Turn Indicator Switches
6. Primary Connector
7. Secondary Connector (yellow)
8. Trailer ABS Malfunction
9. ABS Power
10. Left Turn Indicator Light
11. Brake Lights
12. Right Turn Indicator Light
13. Tail Lights
14. Trailer ABS ECU
15. Power Wire to Trailer ABS
16. ABS Malfunction Wire

Courtesy of Freightliner LLC

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Job Sheet 10

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Student Supplement 7
- DVOM
- Shop towels
- Test light
- Safety glasses
- Tractor/trailer lighting diagnostic tester

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

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Unit 9 Driver Information Systems Diagnosis & Repair

Unit Contents

Student Components

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Student Supplement

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3—Diagnose the Cause(s) of the Faulty Operation of Audible Warning Devices 9–31

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1—Inspect, Test, Repair, and Replace the Components of a Gauge Circuit 9–35
2—Inspect, Test, Repair, and Replace the Components of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit 9–39
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Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose the cause(s) of faulty gauge readings, the faulty operation of audible warning devices and an electronic instrument cluster, and inspect, test, and replace the components of a gauge circuit, electronic instrument cluster, and audible warning devices. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match the basic categories of gauges to descriptions of their operations.
2. Match types of gauges to descriptions of their operations.
3. Match types of gauge sending units to descriptions of their operations.
4. Label the parts of a gauge circuit.
5. Match the names of the parts of a gauge circuit to descriptions of their functions.
6. Label the parts of an electronic instrument cluster, warning light, indicator light, and driver information circuit.
7. Match the names of the parts of an electronic instrument cluster, warning light, indicator light, and driver information circuit to descriptions of their functions.
8. List the types of driver information commonly given by an audible warning device.
9. Label the parts of an audible warning device circuit.
10. Distinguish between outputs of an audible warning device circuit.
11. Diagnose the cause(s) of faulty gauge readings. (Assignment Sheet 1)
12. Diagnose the cause(s) of the faulty operation of an electronic instrument cluster, warning light, indicator light, and driver information circuit. (Assignment Sheet 2)
13. Diagnose the cause(s) of the faulty operation of audible warning devices. (Assignment Sheet 3)
14. Inspect, test, repair, and replace the components of a gauge circuit. (Job Sheet 1)

15. Inspect, test, repair, and replace the components of an electronic instrument cluster, warning light, indicator light, and driver information circuit. (Job Sheet 2)

16. Inspect, test, repair, and replace components of audible warning device circuits. (Job Sheet 3)

17. Inspect, test, replace, and calibrate electronic speedometer, odometer, and tachometer circuits. (Job Sheet 4)

Information Sheet

Objective 1

Basic categories of gauges and descriptions of their operation

Note: A gauge monitors and displays information about various vehicle operating systems.

a. **Bimetallic gauge**—converts the heating effect of electricity into mechanical movement

b. **Electromagnetic gauge**—converts the interaction of electromagnets into mechanical movement

Note: Both types of gauges are electromagnetic gauges that react to changes in a sending unit

c. **Electronic (digital) gauge**—converts an analog signal into a digital display

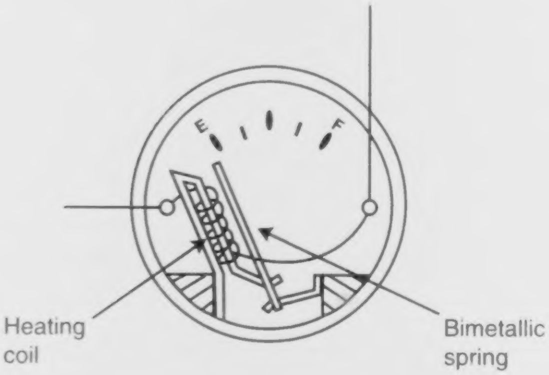
Objective 2

Types of gauges and descriptions of their operation

a. **Bimetallic gauge**—a U-shaped bimetallic strip that bends in proportion to the heat from an attached heating coil to move a pivoted needle or pointer along the calibrated scale of the gauge (Figure 1)

Note: The bimetal strip moved because two different metals are heated and expand at different rates, causing the metal to bend.

Figure 1



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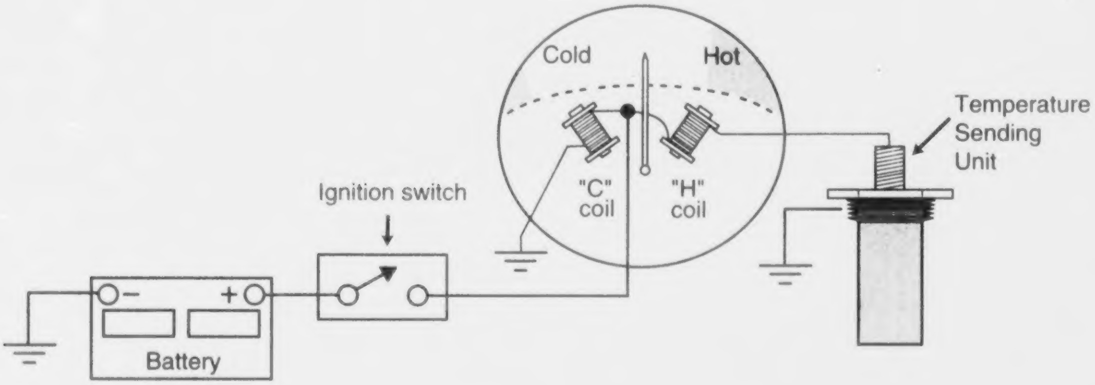
b. **Electromagnetic gauge**—a permanent magnet surrounded by one or more electromagnets that uses the interaction of like and unlike poles to move a pointer or needle along the calibrated scale of the gauge (Figure 2)

Note: Three common types of electromagnetic gauges are the d'Arsonval, the three or two coil, and the air coil.

Figure 2—Two-Coil Temperature Gauge



c. **Electronic (digital) gauge**—receives information from a sensor that contains a permanent magnet creating a magnetic field that when broken, generates an AC voltage sent to a computer module that performs electronic computations and displays the information to the digital gauge

Objective 3

Types of gauge sending units and descriptions of their operation

a. **Mechanical variable resistor (potentiometer)**—resistance value changes in proportion to position of mechanical device; measures fuel levels by using a mechanical float (Figure 3)

b. **Piesoresistor**—resistance value changes in proportion to pressure changes; measures oil pressure (Figure 4)

c. **Thermistor**—resistance value changes in proportion to temperature changes; measures engine coolant temperature (Figure 5)

d. **Pulse generator**—converts mechanical motion to an alternating current pulse that a microprocessor or gauge converts to revolutions per minutes or miles per hours

Figure 3—Mechanical Variable Resistor

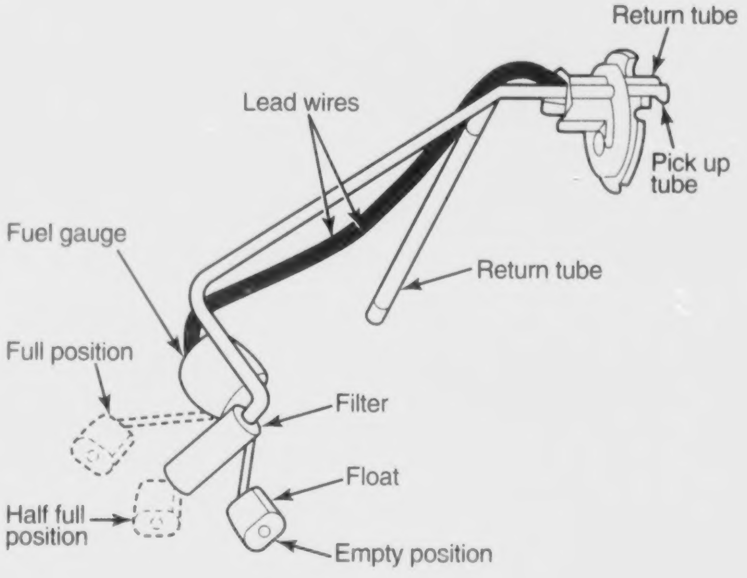

Return tube
Lead wires
Pick up tube
Fuel gauge
Return tube
Full position
Filter
Float
Half full position
Empty position

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Figure 4—Piesoresistor Sensor

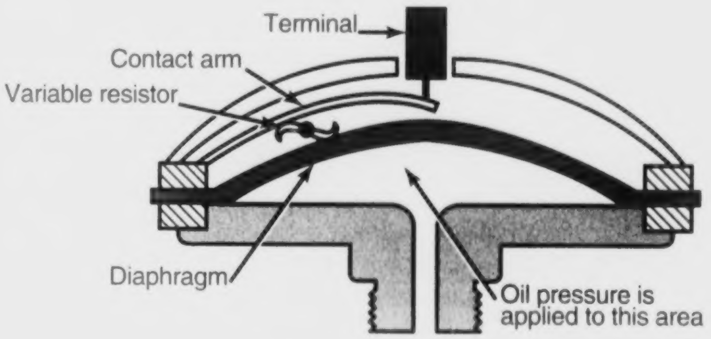
Terminal
Contact arm
Variable resistor
Diaphragm
Oil pressure is applied to this area

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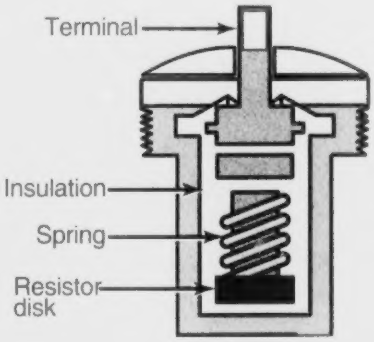
Figure 5—Thermistor


Terminal
Insulation
Spring
Resistor disk

Note: Bimetallic and electromagnetic gauges react differently to sending units.

Objective 4

Parts of a gauge circuit

Figure 6—Bimetallic Gauge Circuit

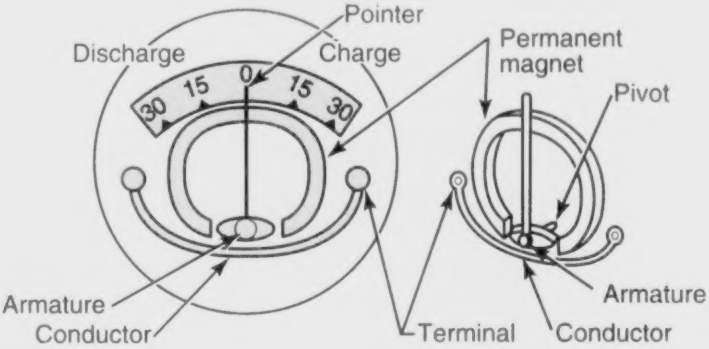

Pointer
Discharge
Charge
30
15
0
15
30
Permanent magnet
Pivot
Armature
Conductor
Terminal
Armature
Conductor

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Figure 7—Electromagnet Two-Coil Gauge Circuit

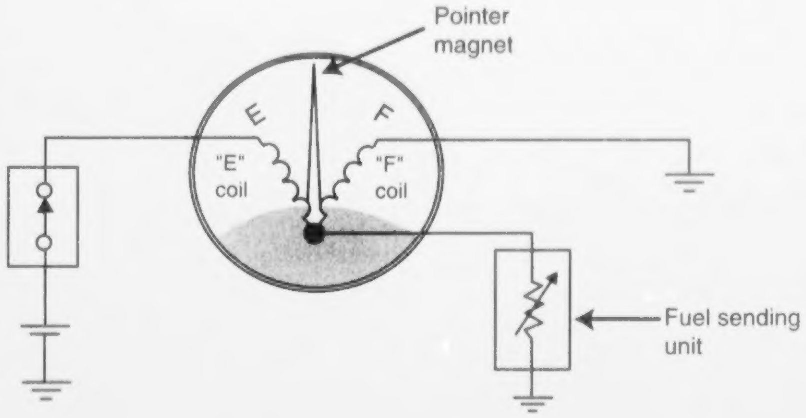
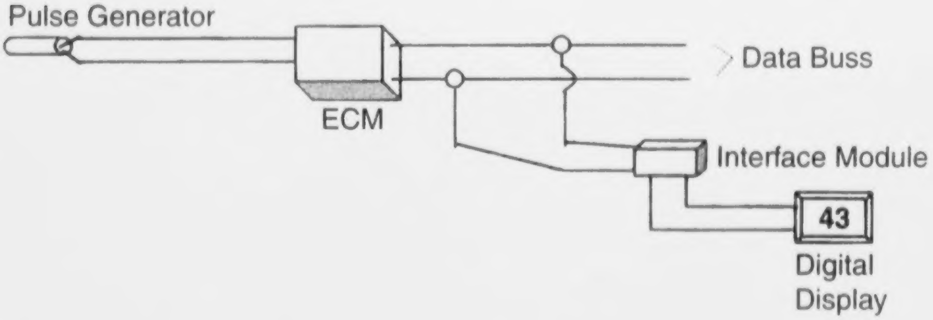

Pointer magnet
E
F
"E" coil
"F" coil
Fuel sending unit

Figure 8—Electronic Gauge Circuit


Pulse Generator
Data Buss
ECM
Interface Module
43
Digital Display

Objective 5

Parts of a gauge circuit and descriptions of their functions

a. **Bimetallic Gauge Circuit**

- **Bimetallic arm**—bends or flexes to move a needle or pointer in proportion to the amount of heat from the heating coil
- **Heating coil**—current proportionally flows through it to heat the bimetallic arm in direct response to resistance values of the sending unit
- **Sending unit**—changes resistance values to the circuit in response to changes in the system being monitored
- **Needle or pointer**—moves in response to the movement of the bimetallic arm
- **Instrument voltage regulator**—provides a steady, consistent electrical current to the gauge.

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b. **Electromagnetic Two-Coil Gauge Circuit**

- **Electromagnetic coils E and F**—use current flow to produce a strong magnetic field to attract the needle or pointer
- **Needle or pointer**—moves in response to the magnetic fields of coils E and F
- **Sending unit**—changes resistance values to the circuit in response to changes in the system being monitored

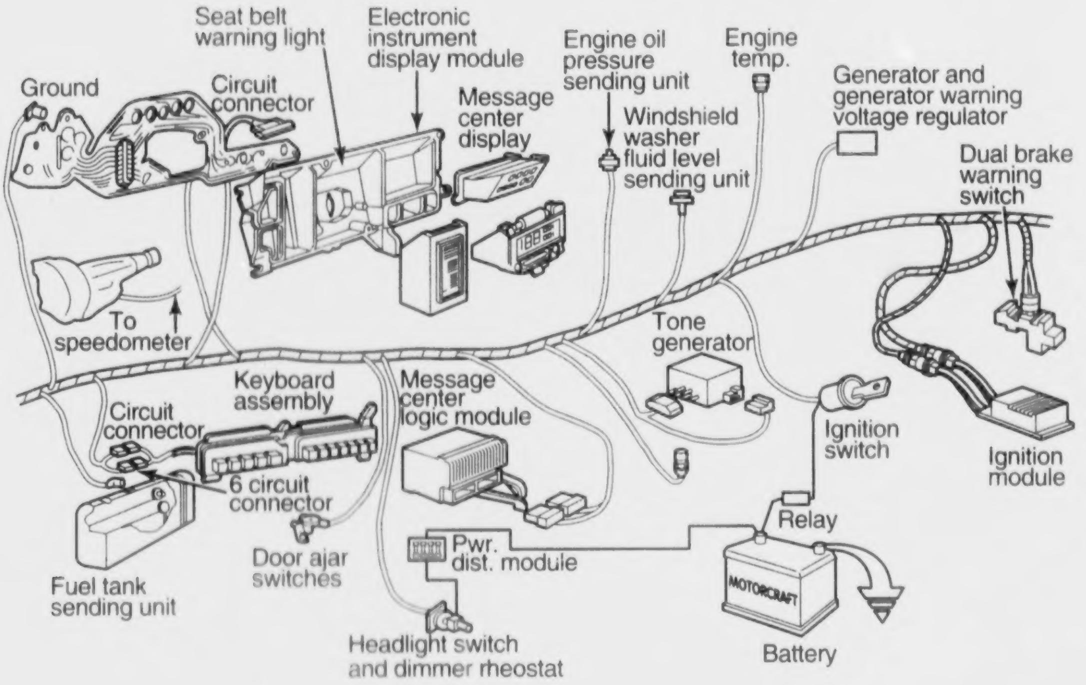
c. **Electronic (digital) Gauge**

- **Pulse generator**—sends a number of analog AC pulses, per revolution, to the ECM (microprocessor)
- **ECM** (microprocessor)—converts analog pulses to digital data and sends them over the data buss
- **Data buss**—a digital 2-way communication highway for several processors that request information from the ECM
- **Interface module**—receives the information it requests from the ECM; then sends this digital information to several different types of digital displays
- **Digital display**—can be of several different types, such as a computerized digital dash, or a stand-alone digital gauge that interrupts the signal and displays the information

Objective 6

Parts of an electronic instrument cluster, warning light, indicator light, and driver information circuits

Figure 9


Seat belt warning light
Electronic instrument display module
Engine oil pressure sending unit
Engine temp.
Ground
Circuit connector
Message center display
Generator and generator warning voltage regulator
Windshield washer fluid level sending unit
Dual brake warning switch
To speedometer
Tone generator
Keyboard assembly
Message center logic module
Circuit connector
Ignition switch
Ignition module
6 circuit connector
Relay
Pwr. dist. module
Door ajar switches
Fuel tank sending unit
MOTORCRAFT
Headlight switch and dimmer rheostat
Battery

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Objective 7

Parts of an electronic instrument cluster, warning light, indicator light, and driver information circuits, and descriptions of their functions

a. **Circuit connector**—holds paired terminals firmly in place, making sure the terminals stay in contact despite the normal vibration of the vehicle

b. **Alternator and alternator warning voltage regulator**—provides a steady, consistent electrical current to the alternator and alternator warning system

c. **Door ajar switches**—connects and disconnects the circuit from the voltage when the door is opened and closed

d. **Dual brake warning switch**—connects and disconnects the circuit from the voltage when the brake is applied

e. **Electronic instrument display module**—displays various operating information for the driver

Note: This module usually contains the speedometer, fuel gauge, coolant temperature gauge, mechanical odometer, transmission select indicator, turn signal indicators, and a high-beam indicator. Bar graphs, vacuum fluorescent character displays, liquid crystal character display, and light emitting diodes may be used to provide the driver with vehicle system information.

f. **Engine oil pressure sending unit**—uses a piesoresistive sensor that changes resistance in proportion to pressure changes

g. **Engine temperature sending unit**—uses a thermistor sensor that changes resistance as temperature changes the input information to the message center logic module

h. **Fuel tank sending unit**—as the fuel level changes, the fuel level float moves the sliding contact on a potentiometer which changes the resistance in the circuit

Note: When the bar gauge reaches a predetermined level, an audible or light signal may be engaged to warn the driver that the fuel tank is nearly empty.

i. **Power distribution module**—holds fuses and circuit breakers

j. **Ground**—conducts current from the vehicle body to the negative terminal of the battery

k. **Headlight switch and dimming rheostat**—increases or decreases resistance in the circuit to produce brighter or dimmer instrument panel lighting

l. **Ignition switch**—connects and disconnects the circuit from the voltage as the switch is moved to the open or closed position

m. **Keyboard assembly**—device by which operator data-entry can determine various trip log/fuel economy function

Note: Some keyboard assemblies have built-in self-test capabilities.

n. **Light bulb outage module**—processes electrical input and applies an appropriate light display to reflect light bulb's outage

o. **Message center display**—reflects a variety of information from monitored engine systems

Note: This display may include fuel remaining, instant fuel economy, average fuel economy, distance to empty, outside temperature, low washer fluid, airbag, and other vehicle conditions.

p. **Message center logic module**—processes electrical input and applies an appropriate message signal for display

q. **Relay**—connects and disconnects the circuit from the voltage

r. **Seat belt warning light**—reflects seat belt not in use

s. **Tone generator**—processes electrical input and applies an appropriate audible signal

t. **Windshield washer fluid sensing unit**—as the windshield washer fluid level changes, the windshield washer level float moves the sliding contact on a potentiometer

Objective 8

Types of driver information commonly given by audible warning devices

a. Anti-theft system activated

b. Door ajar

c. Headlights on

d. Key in ignition

e. Low fuel

f. Low oil pressure

g. Seat belts not buckled

h. Low air pressure

i. High temperature

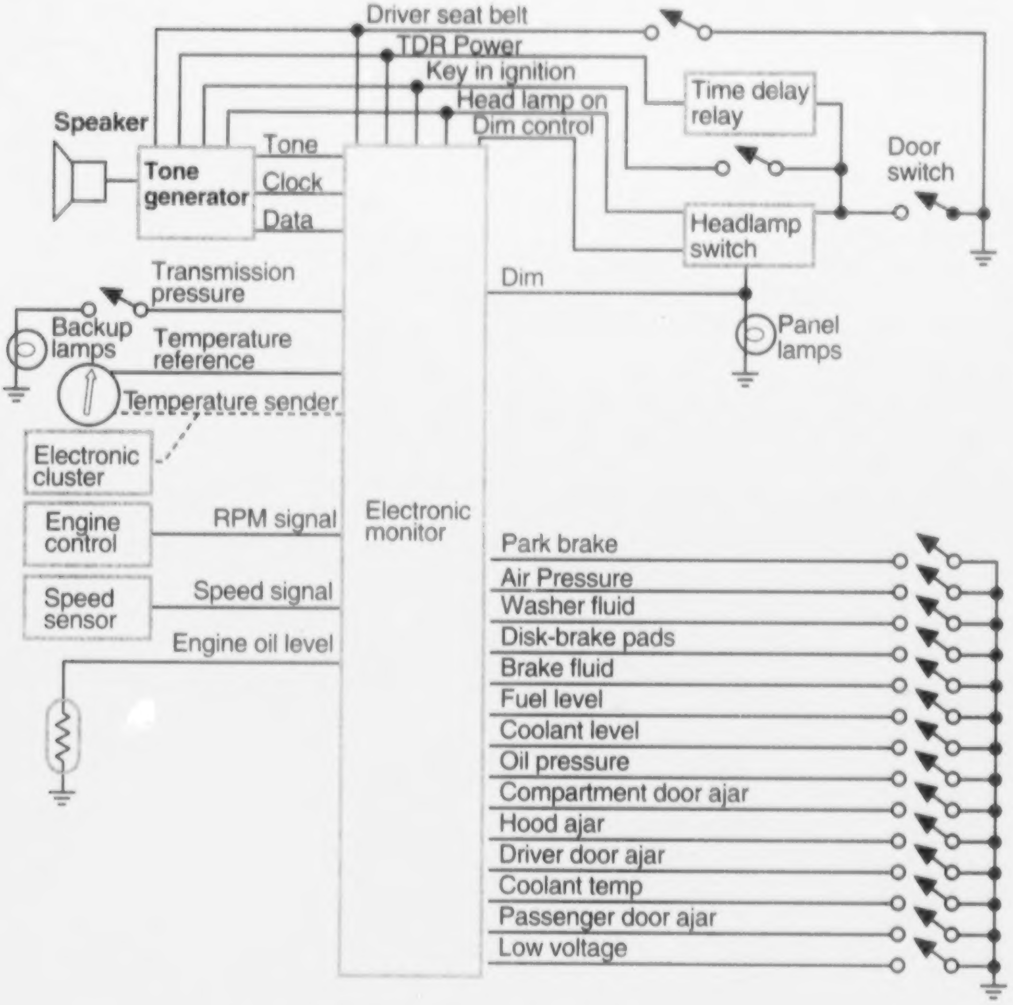
j. Low coolant

k. Low voltage

Objective 9

Parts of an audible warning device circuit

Figure 10


Driver seat belt
TDR Power
Key in ignition
Head lamp on
Dim control
Speaker
Tone
Clock
Data
Tone generator
Time delay relay
Door switch
Headlamp switch
Dim
Panel lamps
Transmission pressure
Backup lamps
Temperature reference
Temperature sender
Electronic cluster
Engine control
RPM signal
Electronic monitor
Speed sensor
Speed signal
Engine oil level
Park brake
Air Pressure
Washer fluid
Disk-brake pads
Brake fluid
Fuel level
Coolant level
Oil pressure
Compartment door ajar
Hood ajar
Driver door ajar
Coolant temp
Passenger door ajar
Low voltage

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Objective 10

Outputs of an audible warning device circuit and descriptions of their functions

a. **Speaker**—amplifies sound made by tone generator

b. **Tone generator**—processes electrical input and applies an appropriate audible signal

Student Supplement 1—Gauges and Sending Units

Gauges

Gauge systems monitor and display information about the function, convenience and safety of the vehicle. They report on a condition, a value of a variable, a change, or a safety feature. Gauges are designed to inform the driver of a developing problem such as fuel level, engine and coolant temperature, oil pressure, charging system, and turbo boost pressure.

Gauges measure physical conditions (pressure, temperature, or fluid level). They do this by using a sending unit that converts mechanical signals from a sensor into an equivalent electrical resistance output. This varying resistance output signal drives the gauge head or display device. A sending unit is not needed when the quantity to be measured is already in electrical form.

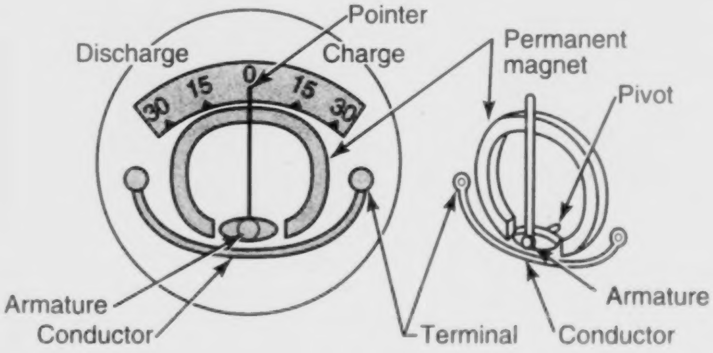
Many vehicles now have electronic gauges incorporated into the electronic instrument cluster. A microprocessor processes information and controls the gauge head or display device. Electronic gauges may display driver information using visual, color or auditory discrimination. Inputs to the microprocessor include electrical messages from sending units, switches and/or other mechanical devices. Most sending units require analog inputs; microprocessors require digital inputs. Analog-to-digital converters convert analog signals to digital codes appropriate for signal processing by the microprocessor.

Two basic types of gauges are bimetallic and electromagnetic gauges:

- A *bimetallic* gauge converts the heating effect of electricity into mechanical movement. It uses a U-shaped bimetallic strip that bends in proportion to the heat from an attached heating coil. This movement pulls a pivoted needle or pointer along the calibrated scale of the gauge head.
- An *electromagnetic* gauge converts the interaction of electromagnets into mechanical movement. A permanent magnet surrounded by one or more electromagnets uses the interaction of like and unlike poles to move a pointer or needle along the calibrated scale of the gauge head.

Three common types of electromagnetic gauges are the d'Arsonval, the three- or two-coil, and the air core. The d'Arsonval has a permanent horseshoe magnet that encompasses a movable electromagnet attached to a pivoted needle or pointer (Figure 1). If the current that flows to the electromagnet is weak, the field will be weak. The needle or pointer will not move very much. If the current flow is increased, the needle movement will be greater.

Figure 1


Pointer
Discharge
Charge
30
15
0
15
30
Permanent magnet
Pivot
Armature
Conductor
Terminal
Armature
Conductor

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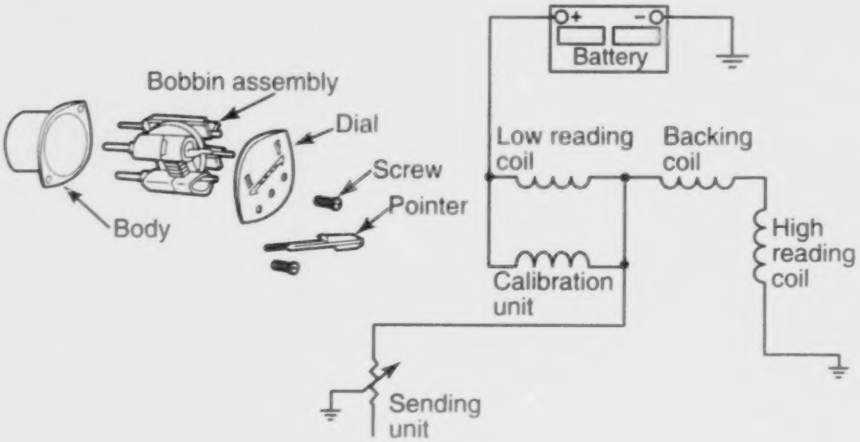
Surrounded by three electromagnets, the permanent magnet of a three-coil gauge (sometimes called a magnetic bobbin gauge) and a two-coil gauge responds to the magnetic interaction of electromagnetic coils (Figure 2). With a three-coil gauge, current flows either (1) through the low-reading coil and through the sending unit to ground, or (2) through the low-reading coil to the bucking coil, and the high reading coil to ground. These two paths of current determine the movement of the needle. The needle responds to the most powerful magnetic field. Because current flows through the path of least resistance, when resistance is equal in the two paths, the needle will be in midrange.

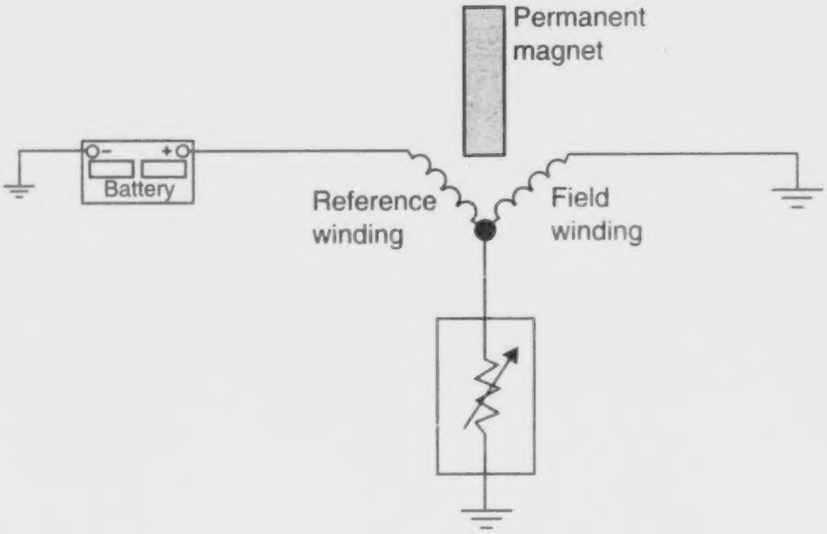
Figure 2


Bobbin assembly
Dial
Screw
Pointer
Body
+
−
Battery
Low reading coil
Backing coil
High reading coil
Calibration unit
Sending unit

11.0

The air core gauge works on the same principle as the three-coil and the two-coil gauge. The difference is that the pointer is connected to a permanent electromagnet (Figure 3). Two windings with no core are placed at different angles and wound around each other. The sending unit's level of resistance determines the movement of the needle.

Figure 3



Instrument Voltage Regulator (limiter)

The Instrument Voltage Regulator (IVR) is designed to protect some gauges that are designed to operate at a constant voltage. The IVR protects these gauges against voltage fluctuations caused by charging system operation. Regardless of charging system output, the IVR limits voltage to the gauge to 5 volts.

Sending Units

- *Coolant Temperature Sending Unit*—A coolant temperature sending unit may use a semi-conductor called a thermistor or a ground wire to detect changes in coolant temperature. The typical coolant temperature sending unit using a thermistor is mounted in a metal housing inserted into the coolant stream. The housing is sealed to prevent leakage. The thermistor varies its resistance in proportion to temperature. It is a solid-state device whose resistance decreases with increasing temperature. The sending unit output voltage is converted to a binary number. A computer compares the number to the maximum safe value stored in memory. If temperature exceeds the limit, an output signal is generated.

Note: Coolant temperature sending units can be either positively or negatively grounded depending on the vehicle's grounding system. If a positively grounded vehicle has a defective sending unit, it will peg out to the "hot" side of the gauge. A sending unit that has a negative ground will peg out to the cold side of the gauge.

- *Pressure Sending Unit*—Pressure sending units are used to measure values such as oil, boost, atmospheric, and fuel pressures. A piesoresistive is used to measure resistance in the engine oil pressure circuit. A flexible diaphragm reacts to engine oil pressure by moving a spring, drawing the contact points of the circuit together or apart. During a predetermined time slot, the oil pressure voltage is sampled and converted to a binary number. This number is compared to the one stored in memory. If the oil pressure is below the allowed lower limit or above the upper limit, an output signal is generated to move the gauge head or drive the display device.
- *Mechanical Sending Unit*—Commonly used to measure fuel levels, mechanical sending units use a mechanical variable resistor. Its resistance value changes in proportion to the position of a mechanical device (like a float in a fuel quantity measurement). The float remains laterally near the center of the tank for all fuel levels. A constant current passes through a variable resistor with a potentiometer. The resistor has three electrical connections for its circuit that act as a voltage divider to produce a continuous variable output signal. This signal is proportional to the mechanical position of the float. One connection is at each end of the resistance unit and one is for the sliding contact. When the float rises or falls with the fluid level, the movement is transferred to the sliding contacts of the resistor. As the switch's wiper moves across the resistor, the computer can track the position of the unit.

Objective 11

Assignment Sheet 1—Diagnose the Cause(s) of Faulty Gauge Readings

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

When diagnosing the cause of faulty gauge readings, remember basic circuit diagnostic procedures:

- Visually inspect for damaged or loose wiring under the hood.
- Check connectors for corrosion and dirt build up.
- If none of the gauges or indicators works properly, check the fuse to see if it is blown.
- Inspect the ground wire to make sure it is clean and securely attached.
- When more than one gauge is faulty, inspect the instrument cluster printed circuit for cracks or flaws.

Because many driver information systems are capable of self-testing, a system check may be the next step when diagnosing the cause of faulty gauge readings. Always refer to the appropriate service manual.

Troubleshooting faulty bimetallic gauges and electromagnetic gauges are similar with respect to the possible causes for failure. However, testing methods of the components may differ. In addition, a system with one gauge instead of multiple gauges may have different possible causes for failure. Always refer to the appropriate service manual to determine testing methods.

When diagnosing a single bimetallic gauge or electromagnetic system, follow the chart below:

Assignment Sheet 1

(1) **CONDITION**	(2) **POSSIBLE CAUSES**
inoperative gauge	defective sending unit, gauge, instrument voltage regulator, or circuit wiring
gauge operates but needle or pointer vibrates distance greater than the width of the needle or pointer	defective instrument voltage regulator

When diagnosing multiple bimetallic gauges or electromagnetic gauges, follow the chart below:

(1) **CONDITION**	(2) **POSSIBLE CAUSES**
one inoperative gauge	defective gauge, sending unit, printed circuit wiring, sending unit ground wire, or wire from gauge to sending unit
all gauges inoperative	defective fuse, fusible link, instrument voltage regulator, or printed-circuit wiring

Directions

Review and use the information found in the Information Sheet, Student Supplement 1, *Gauges and Sending Units*, and the introduction to the assignment sheet to answer the following questions. Write the correct letter in the blank provided.

____ 1. A bimetallic fuel gauge indicates a level lower than its actual level. All other gauges operate normally. Technician A says the problem is probably caused by high resistance in the sending unit ground wire. Technician B says the problem is probably caused by a defective fusible link. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 2. All of the gauges in a multiple bimetallic gauge system are operating irregularly. Technician A says the problem is probably caused by a faulty generator. Technician B says the problem is probably caused by a defective instrument voltage regulator. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 3. All of the gauges in a multiple electromagnetic gauge system are operating irregularly. Technician A says the problem is probably caused by a faulty generator. Technician B says the problem is probably caused by a defective instrument voltage regulator. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 4. An electromagnetic fuel gauge indicates a level lower than its actual level. All other gauges operate normally. Technician A says the problem is probably caused by high resistance in the sending unit ground wire. Technician B says the problem is probably caused by a defective fusible link. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 5. One electromagnetic gauge is out in a multiple electromagnetic gauge system. Technician A says a visual inspection for damaged or loose wiring is one of the first steps in diagnosing the problem. Technician B says that a visual inspection for a corroded connector is one of the first steps. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 6. All of the electromagnetic gauges are inoperative in a multiple electromagnetic gauge system. Technician A says a defective fuse or fusible link may be the problem. Technician B says that a visual inspection for a cracked instrument printed circuit may be the problem. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 7. Technician A says an instrument voltage regulator provides a constant voltage to the coils of a bimetallic gauge. Technician B says it provides a constant voltage to the needle of the gauge. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 8. The needle or pointer on an electromagnetic engine temperature gauge remains in the low position. However, the temperature is in a normal range. Which of the following is **not** a possible cause?

a. Defective sending unit
b. Defective fuse
c. Defective printed circuit wiring
d. None of the above

____ 9. The needle or pointer on a bimetallic oil pressure gauge fluctuates between high and low even though the oil pressure tests indicate a normal reading. Which of the following is **not** a possible cause?

a. Defective sending unit
b. Defective fuse
c. Defective printed circuit wiring
d. None of the above

10. Look up the gauge system check table in a service manual. List the normal results of the oil pressure gauge, engine temperature gauge, fuel gauge and coolant temperature gauge when the ignition switch is initially switched to the ON position.

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Objective 12

Assignment Sheet 2—Diagnose the Cause(s) of the Faulty Operation of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 6 of the 7 questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading Mathematics Science Critical Thinking

Introduction

When diagnosing the cause of a faulty electronic instrument cluster, warning light, indicator light, and driver information circuit, remember basic circuit diagnostic procedures:

- Visually inspect for damaged or loose wiring under the hood.
- Check connectors for corrosion and dirt build up.

Many electronic instrument displays have self-diagnostic capabilities. A self-test routine may verify that the circuit is operating properly. In some electronic instrument displays, a specific gauge illumination or digital display indicates defects in the display. Other electronic instrument displays may be diagnosed with a scan tester. Always refer to the appropriate service manual and system check table.

When the ignition switch is turned on, all parts of many electronic instrument cluster displays should be brightly lit for a few seconds. If some displays are not illuminated, some manufacturers will suggest replacing the electronic instrument cluster printed circuit or module sections of the printed circuit. When none of the segments are illuminated, check the fuses and the voltage supply to the display.

If the warning lights don't briefly illuminate when the ignition is turned on, the bulb may be burned out and must be replaced. If two or more lights do not operate, check the instrument cluster fuse or fusible link. Replace it if it is blown. Check wiring for an open circuit, a defective sending unit, or an open prove-out circuit.

Assignment Sheet 2

Electronic Instrument Cluster, Warning Light, Indicator Light and Driver Information Operation

An electronic instrument cluster may use a combination of warning lights, gauges, indicator lights and audible warnings to relay information about vehicle condition or status. Drivers who do not regularly monitor gauges may first notice a loss in oil pressure when a knocking sound comes from the engine. Therefore, some vehicles use both warning lights and sounds (audible warnings) in addition to a gauge head or display unit to indicate a problem. Warning systems automatically light up and/or chime when something is about to go wrong. Some warning systems use a voice synthesizer to alert the driver of a system condition or status.

A warning light system may use a light-emitting diode (LED), liquid crystal (LCD), vacuum-fluorescent (VFD), or cathode ray tube (CRT) to light the appropriate segment of the instrument cluster.

- The LED display is a solid-state device that emits light when current is passed through its diode. The LED is usually made of small dots arranged so that numbers and letters are formed when selected dots are turned on.
- The LCD display uses polarized light to display numbers and characters on a pneumatic liquid crystal.
- The VFD display uses a material called phosphor that emits a light when it is blasted by electrons. A filament coated with material that generates free electrons when the filament is heated is used to blast the electrons onto the phosphor material.
- The CRT display has the greatest flexibility for displaying messages or pictorial information. It is most commonly used in personal computers. In CRT display devices, a special electronics system called the CRT controller drives the display.

Warning lights may use a simple switch instead of a sending unit to pass signal input to the electronic instrument display module. For example, the door ajar switches and the low washer fluid switch send an input signal to the electronic instrument display module if a door is ajar or the washer reservoir is low. When one of these signals is received, the electronic instrument display module grounds the appropriate bulb. The exception to the simple switch may be a voltage-controlled warning light that uses voltage drop to control the circuit.

The simple switch may be opened or closed, depending on the circuit. With an open switch the contacts are not closed when the ignition switch is in the ON position. To perform a bulb check on normally open switches, a prove-out circuit is included. A prove-out circuit completes the circuit to ground when the ignition switch is in the start position. The bulb remains on during engine cranking to indicate that it is working properly.

(1) CONDITION	(2) POSSIBLE CAUSES	(3) CORRECTIVE ACTION
Display totally blank	Blown fuse	Replace fuse.
	Disconnected, loose ground terminal	Service as required.
	Defective electronic instrument display module	Replace electronic instrument display module.
	Defective connector, accessory, or ground circuit wiring	Service as required.
E, F, and S symbols flash continuously	Open sending unit circuit	Service as required.
	Defective fuel sending unit	Replace sending unit.
	Defective electronic instrument display module	Replace electronic instrument display module.
Fuel bars flash on and off continuously	Short in sending unit circuit	Service as required.
	Defective fuel sending unit	Replace sending unit.
	Defective electronic instrument display module	Replace electronic instrument display module.
Does not read full when tank is filled	Defective sending unit	Replace sending unit.
	Incorrect tank select wire ground connection	Correct wiring connection.
	Defective electronic instrument display module	Replace electronic instrument display module.
	Incorrect seating of filler neck to fuel tank, wrong filler neck	Service as required.
Does not read zero when tank is empty	Defective sending unit	Replace sending unit.
	Defective fuel tank	Service as required.
	Defective electronic instrument display module	Replace electronic instrument display module.
	Defective sending unit ground or sending unit circuit.	Service as required.

Assignment Sheet 2

(1) CONDITION	(2) POSSIBLE CAUSES	(3) CORRECTIVE ACTION
Display brightness does not change with dimming control	Blown dimming circuit fuse	Replace fuse.
	Defective electronic instrument display module	Replace electronic instrument display module.
	Defective headlight switch	Replace or service as required.
	Defective dimmer circuit	Service as required
Erratic display. Display blinks on and off	Defective ACC or GND circuit connections	Service as required.
	Defective electronic instrument display module	Replace electronic instrument display module.
E, F, and - symbols or fuel bars flash intermittently	Defective sending unit wiring	Service as required.
	Defective sending unit	Replace sending unit.
	Defective electronic instrument display module	Replace electronic instrument display module.
Fuel bars vary more than two or three bars between engine starts or during normal driving conditions	Sticky fuel sending unit	Replace sending unit.

Directions

Review and use the information found in the Information Sheet, Student Supplement 1, *Gauges and Sending Units*, and the introduction to the assignment sheet to answer the following questions. Write the correct letter in the blank provided.

____ 1. The temperature lamp remains off when the ignition switch is in the ON position. Which of the following is **not** a possible cause?

a. A blown fuse
b. A defective light bulb
c. A defective sending unit
d. An open prove-out circuit

____ 2. A warning light does not light, but it does light when the wire from the light to the sending unit is grounded at the sending unit. What does this indicate?

a. Defective sending unit
b. Defective warning light
c. Open circuit in the light wiring
d. The fuse is blown

____ 3. The fuel bars flash on and off continuously. Which of the following is **not** a possible cause?

a. Short in sending unit circuit
b. Damaged fuel sending unit
c. Damaged instrument cluster module
d. Blown dimming circuit fuse

____ 4. None of the segments of an electronic instrument cluster light up when the ignition switch is in the ON position. Technician A says that a fuse or fusible link may be to blame. Technician B says that a defective printed circuit board is at fault. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 5. Technician A says that the self-testing diagnostic ability of an electronic instrument cluster uses standardized codes. Technician B says that some have individual codes. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 6. Technician A says that a prove-out circuit is engaged when the engine is started. Technician B says that if two or more lights do not operate when the engine is started, the instrument cluster fuse or fusible link is blown. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 7. The fuel gauge symbols flash intermittently. Which of the following is not a possible cause?

a. Defective sending unit wire
b. Defective sending unit
c. Blown fuse
d. None of the above

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Objective 13

Assignment Sheet 3—Diagnose the Cause(s) of the Faulty Operation of Audible Warning Devices

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 4 of the 5 questions correctly per Answers to Assignment Sheet 3	______

Basic Skills

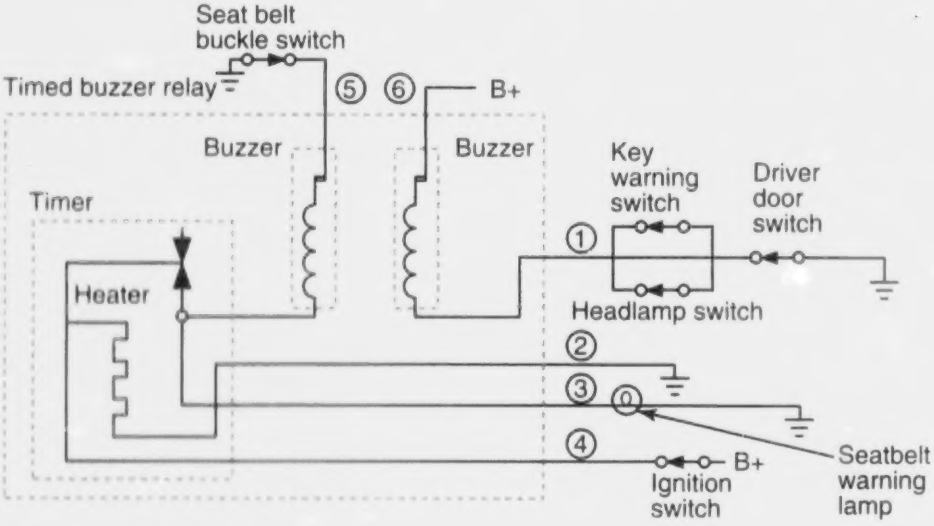
Reading Mathematics Science Critical Thinking

Introduction

Operation

The warning circuit in Figure 1 includes a timer circuit. The seatbelt switch is usually a closed switch. When the seatbelt is fastened, the switch opens. If the engine is started and the seatbelt is not fastened, the switch remains closed, completing the circuit to ground. The warning chime and the light are activated.

Figure 1


Seat belt buckle switch
Timed buzzer relay
⑤
⑥
B+
Buzzer
Buzzer
Timer
Heater
Key warning switch
Driver door switch
①
Headlamp switch
②
③
④
B+
Ignition switch
Seatbelt warning lamp

Used with permission of DaimlerChrysler Corp.

Assignment Sheet 3

The chime for the ignition-key warning system receives its power through a fuse. The buzzer is grounded through two series switches. The key alarm switch is usually in the open position. It is closed when the key is in the ignition switch. The left-door switch closes when the door is open. If the key is in the ignition switch and the left door is open, both switches are closed grounding the buzzer and produces a buzzing sound.

Diagnosis

If the buzzer does not sound, check for a blown fuse. If the fuse is not defective, remove the timer-buzzer from its connector and test with a test lamp. If there is no voltage at the supply terminal, check for an open circuit in the supply wire to the connector. Reconnect the timer-buzzer and connect a jumper wire from the ground terminal to the buzzer to ground. If the buzzer sounds, there is an open circuit between the connector and ground. If the buzzer does not sound, the buzzer is defective and should be replaced.

If the buzzer remains on when the seatbelt is unbuckled, check for an open circuit between the connector and ground. Locate and repair the open circuit. If the buzzer doesn't stop after the appropriate time, the timer is defective and should be replaced.

In addition to signals like buzzers and chimes, some warning systems use synthesized speech. If the voice warning system is completely inoperative or if a particular voice warning in inoperative, the microcomputer is defective. Replace the microcomputer as directed by the service manual.

Directions

Review and use the information found in the Information Sheet and the introduction to the assignment sheet to answer the following questions. Write the correct letter in the blank provided.

____ 1. The seatbelt warning buzzer remains on with the seatbelt unbuckled. What can cause this?

- a. Defective seatbelt switch
- b. Defective timer
- c. Defective warning light
- d. Blown fuse

____ 2. If a warning buzzer will only operate with the ground circuit bypassed with a jumper wire, what should be checked?

- a. Open ground circuit
- b. Defective buzzer
- c. Blown fuse
- d. Open circuit in the voltage supply to the buzzer

____ 3. The ignition-key warning system is not operating properly. Technician A says that a grounded left-door switch is to blame. Technician B says that a defective buzzer is to blame. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and B
d. Neither Technician A nor B

____ 4. The seatbelt buzzer and the seatbelt light operate continually with the ignition switch on and the driver's seatbelt buckled. Which of the following is **not** a possible cause?

a. Blown fuse
b. Defective buzzer
c. Open ground circuit
d. Defective timer buzzer circuit

____ 5. The voice warning system is completely inoperative. Which of the following is **not** a possible cause?

a. Blown fuse
b. Defective microcomputer
c. Defective sending unit
d. Defective resistor

Objective 14

Job Sheet 1—Inspect, Test, Repair, and Replace the Components of a Gauge Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

When inspecting the components of a gauge circuit, remember basic circuit diagnostic procedures:

- Visually inspect for damaged or loose wiring under the hood.
- Check connectors for corrosion and dirt build up.
- If none of the gauges or indicators works properly, check the fuse to see if it is blown.
- Inspect the ground wire to make sure it is clean and securely attached.
- When more than one gauge is faulty, inspect the instrument cluster printed circuit for cracks or flaws.

Repairing a gauge circuit may require inspecting, testing, or replacing a sending unit. You can usually remove either type of sending unit by unscrewing it from the engine:

- Oil-pressure sending units tie into the engine oil passage.
- Coolant-temperature sending units tie into the engine-water jacket. When removing a temperature sending unit, drain enough of the coolant so that the coolant level is below the sending unit opening.

> Warning: Shut down the engine and always allow the engine to cool before removing the unit!

Job Sheet 1

Fuel gauge sending units are held in place by a retaining ring or screws, and fit into an opening in the fuel tank:

- When removing a fuel-tank sending unit, make sure the level of fuel is below the sending unit opening.
- Use a hammer and a punch to drive the retaining ring in a counterclockwise direction, or a screwdriver to remove the screws.
- Pull the sending unit out through the opening in the tank when the retaining ring or screws have been removed.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Refer to the appropriate service manual for the make and model as equipped.

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 15

Job Sheet 2—Inspect, Test, Repair, and Replace the Components of an Electronic Instrument Cluster, Warning Light, Indicator Light, and Driver Information Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

- Visually inspect for damaged or loose wiring under the hood.
- Check connectors for corrosion and dirt build up.
- Many electronic instrument displays have self-diagnostic capabilities. A self-test routine may verify that the circuit is operating properly. In some electronic instrument displays a specific gauge illumination or digital display indicates certain defects in the display. Other electronic instrument displays may be diagnosed with a scan tester. Always refer to the appropriate service manual and system check table.
- Many of the components of an electronic instrument cluster are in hard to reach places. You can usually pull the instrument cluster away from the instrument panel.
- A printed circuit is used by most manufacturers. Tracing the printed circuit wiring by following the conducting strips may lead to the discovery of a break, or open circuit, in a conductor. If so, replace the printed circuit.
- Warning lights and indicator lights usually have fiber-optic bundles of special plastic or glass strands that transmit light from a source to a display. If the fiber-optic display operates

  — Check the source of light for correct operation.

- — Check the end of the fiber-optic conductor to make sure it is properly attached.
- — Check the viewing area of the display to see that it is clean.
- — Check the conductor bundles for broken bundles. If bundles are broken, replace them.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Other equipment and supplies as required by the procedure
- Safety glasses
- Scan tester

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Refer to the appropriate service manual for the make and model as equipped.

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made:	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 16

Job Sheet 3—Inspect, Test, Repair, and Replace Components of Audible Warning Device Circuits

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

- Visually inspect for damaged or loose wiring under the hood.
- Check connectors for corrosion and dirt build up.
- Many electronic instrument displays have self-diagnostic capabilities. A self-test routine may verify that the circuit is operating properly. In some electronic instrument displays a specific gauge illumination or digital display indicates certain defects in the display. Other electronic instrument displays may be diagnosed with a scan tester. Always refer to the appropriate service manual and system check table
- A buzzer is usually powered through a courtesy lamp fuse. The buzzer may be grounded through two series switches. When the buzzer is grounded, it produces a buzzing sound. To test for a defective buzzer unit in the key warning system, check the fuse and replace it if it is blown. If the fuse is good, check the buzzer unit by removing it from its connector and using jumper wires connected to the terminals of a 12-volt battery. If the buzzer sounds, it is not defective. If it does not sound, replace it.
- Check the buzzer with a voltmeter or a test lamp to test for voltage at the connector. If there is no voltage, check for an open-circuit in the supply wire. Other sources for a buzzer not operating may be a defective key-alarm or door switch, broken wires, or defective connector.
- The tone generator cannot be repaired. If it is defective, replace it.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 3

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Other equipment and supplies as required by the procedure
- 12-Volt battery
- Jumper wires
- Test light
- Voltmeter
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
	TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________
Address ____________
Phone # ____________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________
Customer Address ____________
Customer Phone # ____________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________

Services/repairs made: ____________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 3

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Objective 17

Job Sheet 4—Inspect, Test, Replace, and Calibrate Electronic Speedometer, Odometer, and Tachometer Circuits

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Electronic Speedometer, Odometer, and Tachometer

Some electronic speedometers and tachometers are separate units mounted into the dash. Other speedometer/tachometer combinations, consisting of a speedometer, tachometer, and odometer, come as a single unit and include a printed circuit board that drives gauges and interfaces with the engine computer.

Electronic (digital) gauge sensors contain a permanent magnet that creates a magnetic field. When broken, the magnetic field generates an AC voltage that is sent to a computer module. The computer performs electronic computations and displays the information on the gauge. The speedometer sensor is usually located in the transmission tail shaft and the tachometer sensor is usually located in the engine flywheel housing.

The two most common customer complaints are that a unit that won't indicate speed or RPM, or that the unit indicates an incorrect speed or RPM.

When a unit won't indicate speed or RPM, the problem usually centers around a:

- computer malfunction
- sensor failure
- defective speedometer/tachometer unit, or an
- open circuit or ground

When a unit indicates an incorrect speed or RPM, the problem is usually caused by a change in tire size or rear axle ratio. In this case, the speedometer/tachometer unit must be re-calibrated.

Calibrating a Speedometer/Tachometer Unit

Speedometer calibration takes into consideration tire size and drive axle ratios, and tachometer calibration takes into consideration the number of flywheel teeth. Calibration is normally performed whenever the speedometer or tachometer heads are replaced, or when tire size or rear axle ratio changes. A set of dip switches is used to calibrate both units. On most vehicles, the calibration unit is located on either the unit housing or in the heads. Dip switches have two settings: either 0 or 1, with 0 being OFF and 1 being ON. Speedometers have 8 or 10 dip switch settings, and tachometers have 8 dip switch settings.

Note: If replacing the speedometer or tachometer with a new unit, note the dip switch settings on the one you're removing and set the dip switches on the new unit to the same settings.

Calculate dip switch settings by following the steps listed below.

1. Calculate pulses per mile (PPM) by multiplying the rear axle ratio times tire revolutions per mile times 16 (number of teeth on the speedometer gear).

   PPM = rear axle ratio X tire revolutions per mile X the number of teeth on the speedometer gear

   Note: The rear axle ratio is usually stamped on the differential carrier or listed on the truck's line sheet. Tire revolutions per mile is calculated by measuring the distance the vehicle moves in one tire revolution, and dividing that number by 5,280 (distance in feet per mile).

2. Calculate the calibration number by dividing pulses per mile by 120.

   Calibration number = PPM/120

   Note: Some manufacturers don't divide by 120. Their charts are based on PPM.

3. Compare the calibration number to the chart listed in the appropriate service manual. The chart will tell you the dip switch settings for that particular calibration number.

1200

Job Sheet 4

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Other equipment and supplies as required by the procedure
- DVOM
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Refer to the appropriate service manual for the make and model as equipped.

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name

Address

Phone #

Date In

Date Out

JOB TICKET

Customer Name

Customer Address

Customer Phone #

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested:

Services/repairs made:

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

Date

Technician

Supervisor

Unit 10 Related Electrical Components

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Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose the cause of horn, wiper, windshield washer, heater, and air conditioner problems, inspect, test, repair, and replace the components of horn, wiper, windshield washer, heater and air conditioning circuits, and replace the components of pulsing wiper controls and engine block heaters. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match the names of the parts of a horn circuit to descriptions of their functions.
2. Label the parts of a horn circuit.
3. Match the names of the parts of a wiper circuit to descriptions of their functions.
4. Label the parts of a windshield washer circuit.
5. Match the names of the parts of a windshield washer circuit to descriptions of their functions.
6. Label the parts of a heater circuit.
7. Match the names of the parts of a heater circuit to descriptions of their functions.
8. Label the major and secondary components of an expansion valve type A/C system.
9. Match the names of the parts of an air conditioning circuit to descriptions of their functions.
10. Distinguish between types of engine block heaters.
11. Diagnose the cause of horn problems. (Assignment Sheet 1)
12. Diagnose the cause of wiper problems. (Assignment Sheet 2)
13. Diagnose the cause of windshield washer problems. (Assignment Sheet 3)
14. Diagnose the cause of heater problems. (Assignment Sheet 4)
15. Diagnose the cause of air conditioning problems. (Assignment Sheet 5)

Objective Sheet

16. Inspect, test, repair, and replace the components of a horn circuit. (Job Sheet 1)
17. Inspect, test, repair, and replace the components of wiper circuits. (Job Sheet 2)
18. Inspect, test, repair, and replace intermittent (pulsing) wiper controls. (Job Sheet 3)
19. Inspect, test, repair, and replace the components of a windshield washer circuit. (Job Sheet 4)
20. Inspect, test, repair, and replace the components of a heater circuit. (Job Sheet 5)
21. Inspect, test, repair, and replace the components of an air conditioning circuit. (Job Sheet 6)
22. Inspect, test, repair, and replace the components of an engine block heater. (Job Sheet 7)

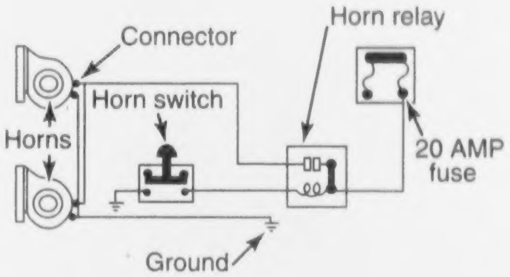
1266

Information Sheet

Objective 1

Parts of a horn circuit and descriptions of their functions

Figure 1



a. **Connector**—plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

b. **Fuse**—protects components of the circuit from short circuits and current overloads

c. **Fusible link**—protects components from excessive current flow and short circuits

d. **Ground circuit**—a common negative connection that provides a path for electricity to return to its source after reaching its intended load and circuits

e. **Horn assembly**—converts electrical energy into mechanical energy to produce sound

Note: Most horn assemblies contain a moveable armature, a diaphragm, and a set of normally closed contact points.

f. **Horn-button switch**—controls current flow to horn assembly to complete the circuit to ground

Note: A horn-button switch may be located on the steering wheel or it may be part of a multifunctional switch.

g. **Relay**—controls current by rapidly switching current on and off

Note: This is usually used when a heavy current load is required.

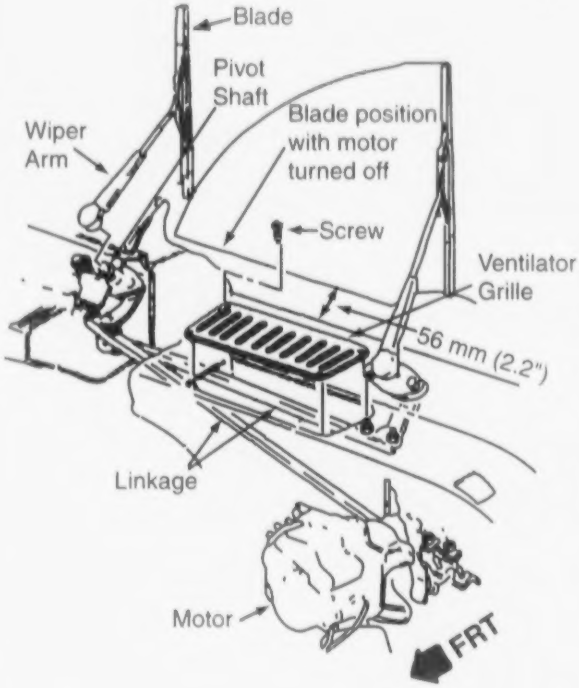
Note: Some vehicles do not use a relay but use the horn-button switch to carry the total current. Depressing the horn-button switch connects the circuit from the battery to the horn assembly.

h. **Wiring**—connects components to the battery and/or each other

Objective 2

Parts of a wiper circuit

Figure 2


Blade
Pivot Shaft
Wiper Arm
Blade position with motor turned off
Screw
Ventilator Grille
56 mm (2.2")
Linkage
Motor
FRT

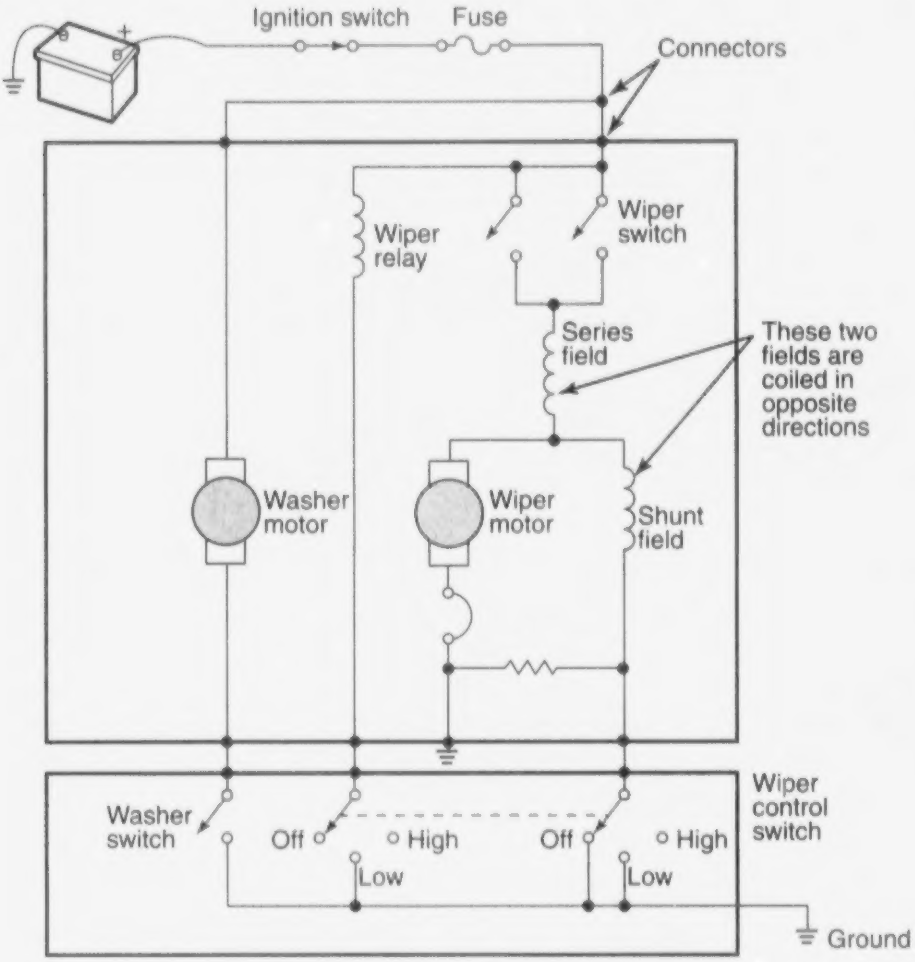
Note: Windshield wipers remove water, snow, dirt, and other foreign materials from the windshield of a vehicle by moving the blades back and forth across the windshield.

Note: Many of today's vehicles also have headlight wipers that work together with the windshield wipers.

Objective 3

Parts of a wiper circuit and descriptions of their functions

Figure 3


Ignition switch
Fuse
Connectors
Wiper relay
Wiper switch
Series field
These two fields are coiled in opposite directions
Washer motor
Wiper motor
Shunt field
Washer switch
Off
High
Low
Off
High
Low
Wiper control switch
Ground

a. **Connector**—plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

b. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

c. **Intermittent wiper circuit**—contains a solid-state module which opens and closes the ground circuit on the low-speed relay winding of the wiper motor to provide the prescribed delay

d. **Relay**—controls current by rapidly switching current on and off

Note: A relay is usually used when heavy current load is required.

e. **Wiper blade**—rubber blade on an arm that moves back and forth over the windshield removing water, snow, dirt, or other foreign matter

f. **Wiper linkage**—transfers the motion from the wiper motor to complete the circuit to ground

g. **Wiper motor**—changes electrical energy into mechanical energy

h. **Wiper switch**—controls current flow to the wiper motor to complete the circuit to ground

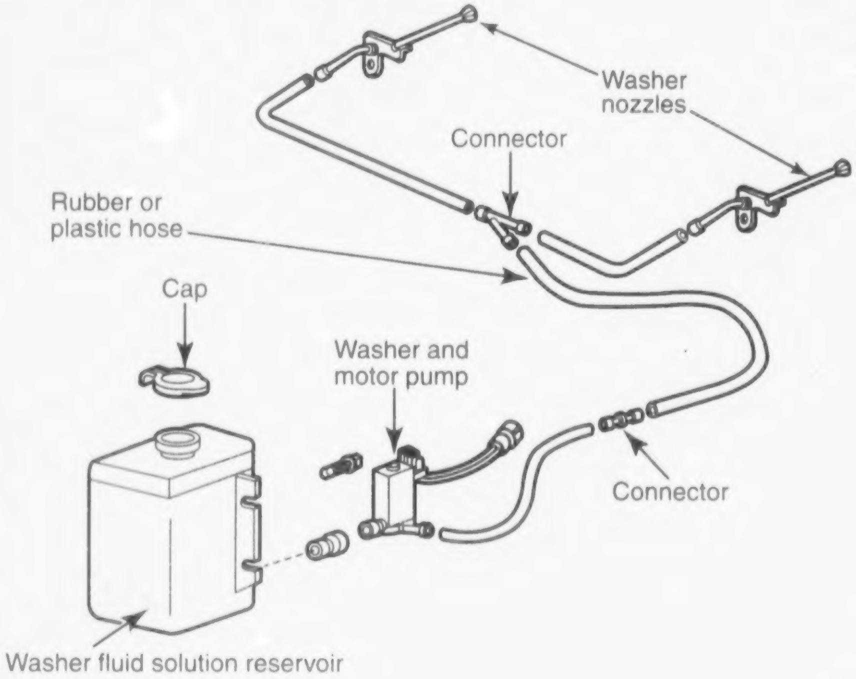
Note: The wiper switch is a multi-function switch that controls the speed of the wiper motor through a rheostat, relay contact switches, and/or variable resistors.

i. **Wiring**—connects components to the battery and/or each other

Objective 4

Parts of a windshield washer circuit

Figure 4

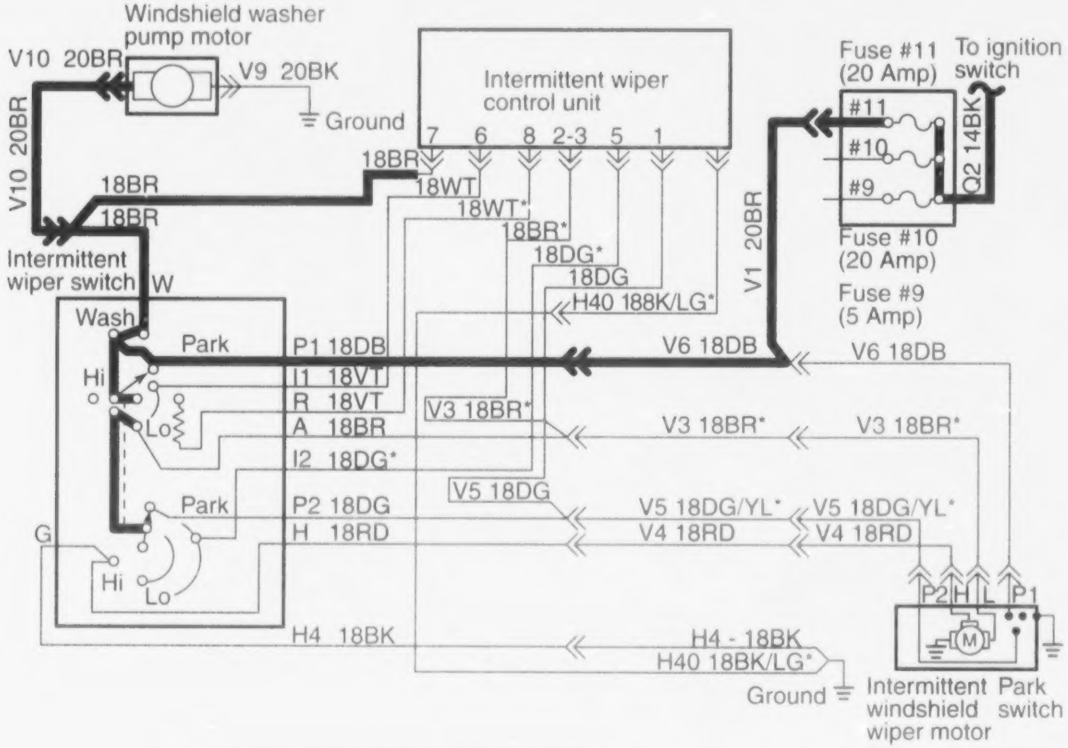

Washer nozzles
Connector
Rubber or plastic hose
Cap
Washer and motor pump
Connector
Washer fluid solution reservoir

Note: The purpose of a windshield washer is to spray fluid on the windshield while working with the windshield wiper blades to remove foreign material from the windshield.

Information Sheet

Objective 5 **Parts of a windshield washer circuit and descriptions of their functions**

Figure 5


Windshield washer pump motor
V10 20BR
V9 20BK
Ground
Intermittent wiper control unit
7
6
8
2-3
5
1
Fuse #11 (20 Amp)
To ignition switch
#11
#10
#9
Q2 14BK
Fuse #10 (20 Amp)
Fuse #9 (5 Amp)
V1 20BR
V10 20BR
18BR
18BR
18BR
18WT
18WT*
18BR*
18DG*
18DG
H40 18BK/LG*
Intermittent wiper switch
W
Wash
Park
Hi
Lo
Park
G
Hi
Lo
P1 18DB
I1 18VT
R 18VT
A 18BR
I2 18DG*
P2 18DG
H 18RD
H4 18BK
V6 18DB
V6 18DB
V3 18BR*
V3 18BR*
V3 18BR*
V5 18DG
V5 18DG/YL*
V5 18DG/YL*
V4 18RD
V4 18RD
H4 - 18BK
H40 18BK/LG*
Ground
P2
H
L
P1
M
Intermittent windshield wiper motor
Park switch

Used with permission of DaimlerChrysler Corp.

a. **Connector**—plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

b. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

c. **Nozzle**—forces washer solution onto the windshield in a spray pattern

Note: Nozzles are usually made of metal but may be made of plastic.

d. **Rubber or plastic hose**—holds washer solution and transports it to the nozzles

e. **Washer pump**—displaces solution from the reservoir into the hoses

f. **Wiper switch**—controls the current flow to the wiper motor to complete the circuit to ground

g. **Wiring**—connects components to the battery and/or each other

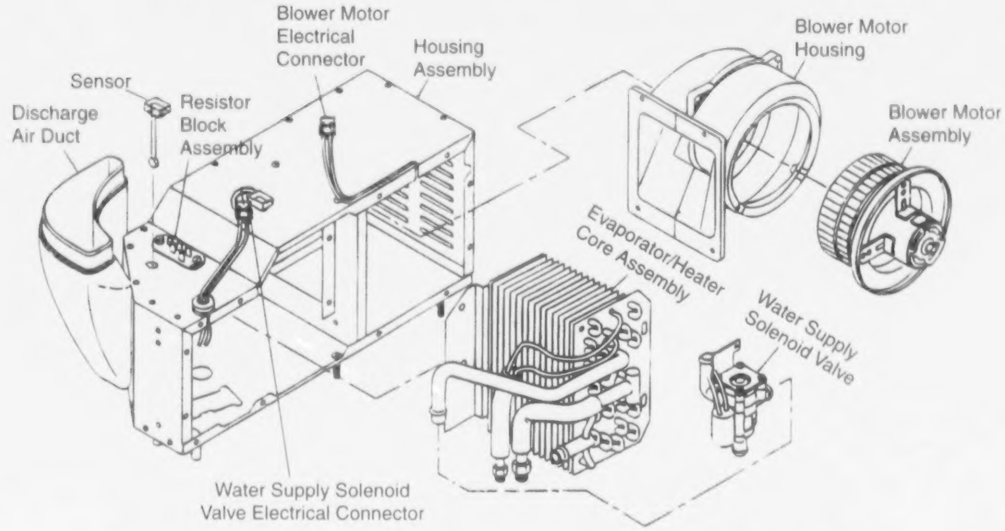
12.2

Objective 6

Parts of a heater circuit

Note: Heaters are heat exchangers that obtain heat from the temperature of circulated engine coolant at the heater core.

Figure 6—Sleeper heater assembly


Blower Motor Electrical Connector
Housing Assembly
Blower Motor Housing
Sensor
Discharge Air Duct
Resistor Block Assembly
Blower Motor Assembly
Evaporator/Heater Core Assembly
Water Supply Solenoid Valve
Water Supply Solenoid Valve Electrical Connector

Courtesy of Freightliner LLC

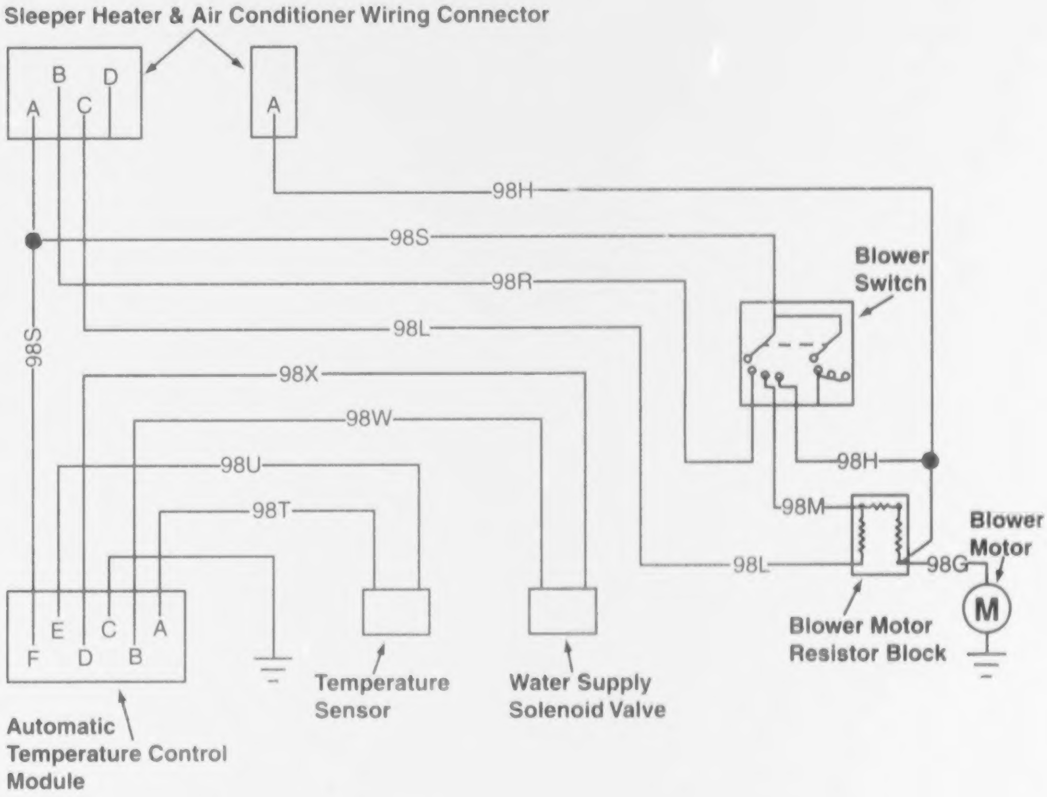
Note: Heavy vehicles with a sleeper cab may have two separate heating systems.

Information Sheet

Objective 7

Parts of a heater circuit and descriptions of their functions

Figure 7


Sleeper Heater & Air Conditioner Wiring Connector
A
B
C
D
A
98H
98S
98R
98L
98S
98X
98W
98U
98T
Blower Switch
98H
98M
98L
98G
Blower Motor
M
Blower Motor Resistor Block
E
C
A
F
D
B
Temperature Sensor
Water Supply Solenoid Valve
Automatic Temperature Control Module

Courtesy of Freightliner LLC

a. **Blower control switch**—controls current flow to the blower motor which regulates the amount of air delivered through the cab and sleeper vents

b. **Blower motor**—converts electrical energy to mechanical energy to operate the blower fan

c. **Circuit breaker**—protects components of the circuit from temporary current overloads

Note: Circuit breakers are sometimes found in place of fuses on heavy-duty trucks. When excessive current flow is present, it "trips" and stops current flow. Once the circuit has cooled or the fan switch has been turned off, the circuit breaker will automatically reset itself.

d. **Connector**—plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

e. **Cooling tube**—cools the blower motor by circulating air around the motor

Note: Some blower motors do not use a cooling tube. Instead, they are cooled by air forced through vents in the blower motor housing.

f. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

g. **Heater, cab/sleeper**—heat exchanger which obtains heat from the circulated engine coolant at the heater core

h. **Relay**—controls current by rapidly switching current on and off

i. **Resistor block**—used to cause a voltage drop that controls the different speeds of the blower motor

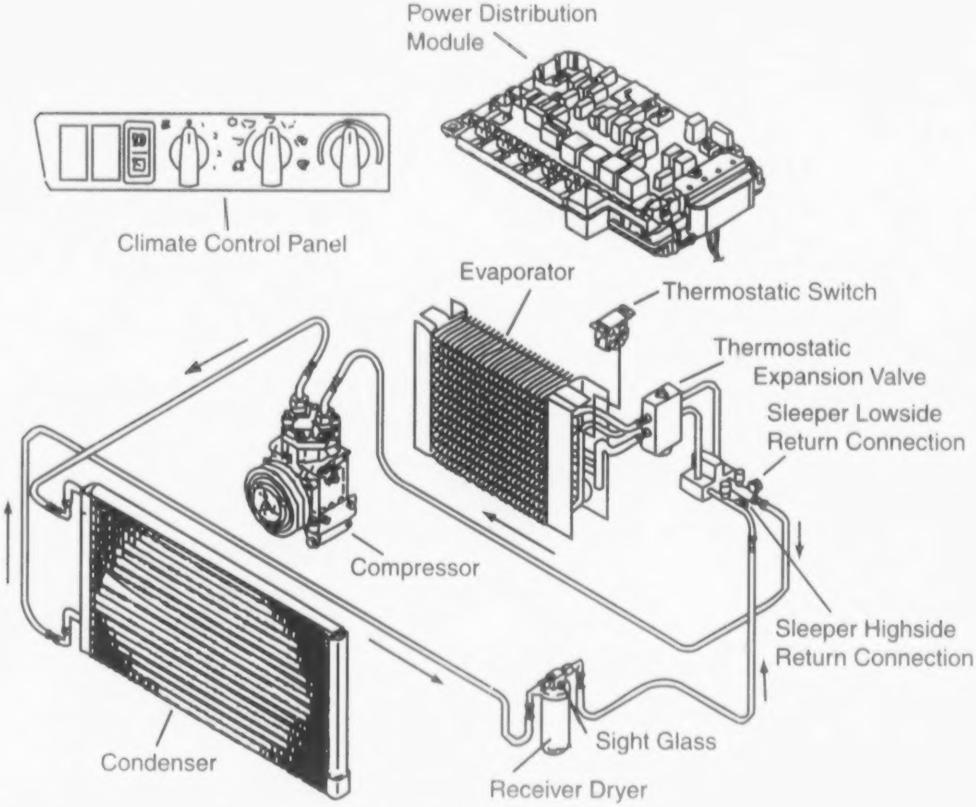
j. **Temperature control module**—computer unit that maintains a specific temperature automatically inside the cab compartment through employment of numerous temperature sensors

k. **Wiring**—connects components to the battery and/or each other

Objective 8

Major and secondary components of an expansion valve type A/C system

Figure 8

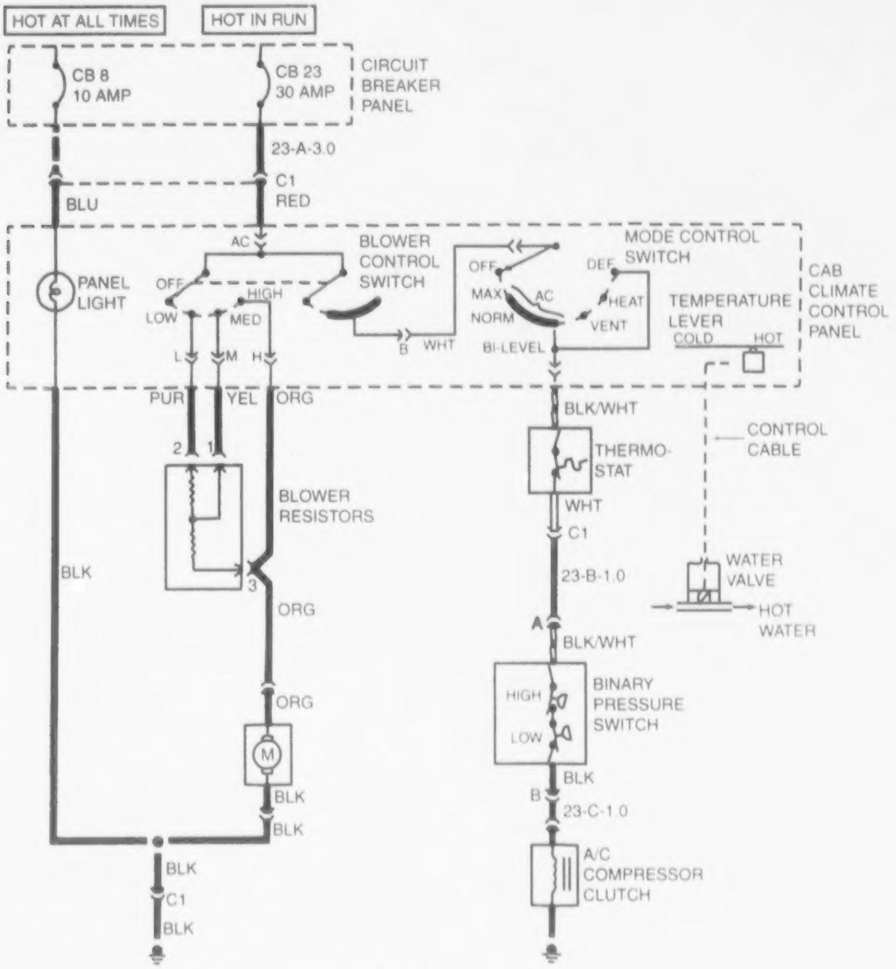

Power Distribution Module
Climate Control Panel
Evaporator
Thermostatic Switch
Thermostatic Expansion Valve
Sleeper Lowside Return Connection
Compressor
Sleeper Highside Return Connection
Sight Glass
Condenser
Receiver Dryer

Courtesy of Freightliner LLC

Objective 9

Parts of an air conditioning circuit and descriptions of their functions

Figure 9


HOT AT ALL TIMES
HOT IN RUN
CB 8
10 AMP
CB 23
30 AMP
CIRCUIT
BREAKER
PANEL
23-A-3.0
C1
RED
BLU
AC
BLOWER
CONTROL
SWITCH
MODE CONTROL
SWITCH
CAB
CLIMATE
CONTROL
PANEL
PANEL
LIGHT
OFF
LOW
HIGH
MED
OFF
MAX
NORM
AC
DEF
HEAT
VENT
BI-LEVEL
B
WHT
TEMPERATURE
LEVER
COLD
HOT
L
M
H
PUR
YEL
ORG
2
1
3
BLOWER
RESISTORS
BLK
ORG
ORG
M
BLK
BLK
BLK
C1
BLK
BLK/WHT
THERMO-
STAT
WHT
C1
23-B-1.0
A
BLK/WHT
HIGH
LOW
BINARY
PRESSURE
SWITCH
BLK
B
23-C-1.0
A/C
COMPRESSOR
CLUTCH
CONTROL
CABLE
WATER
VALVE
HOT
WATER

Courtesy of Mack Trucks Inc.

a. **Accumulator**—used in an orifice tube system, removes moisture and particles from the liquid refrigerant and prevents liquid refrigerant from entering the compressor

b. **Binary switch**—located on the receiver/dryer, provides low- and high-pressure protection for the system by switching the compressor on or off

c. **Blower control switch**—controls current flow to the blower motor which regulates the amount of air delivered through the cab and sleeper vents

d. **Circuit breaker**—protects components of the circuit from temporary current overloads

Note: Circuit breakers are sometimes found in place of fuses on heavy-duty trucks. When excessive current flow is present, it "trips" and stops current flow. Once the circuit has cooled or the fan switch has been turned off, the circuit breaker will automatically reset itself.

e. **Compressor**—draws low-pressure vapor from the evaporator and compresses it into high-pressure vapor enabling the condenser to change the vapor back into liquid. Also pumps refrigerant through the condenser under different pressures

f. **Condenser**—removes heat from high-pressure hot vapor coming from the compressor and turns it into high-pressure warm liquid

g. **Connector**—plastic component containing one or more terminals that attach wires and wiring harnesses to electrical components and other harnesses

h. **Cycling pressure switch (thermostat)**—senses when a preset temperature is reached in the evaporator and cycles the compressor on and off to prevent the moisture that condenses on the evaporator fins from freezing

i. **Evaporator**—located under the cab's dashboard or instrument panel, receives low-pressure, low-temperature liquid refrigerant from the thermostatic expansion valve or orifice tube in the form of spray. Uses heat from the core surface to boil the refrigerant causing the core to cool. Air passing over the evaporator cools, thereby removing the heat which makes the air feel cool

j. **Ground circuit**—a common negative connection that provides a path for the electricity to return to its source after reaching its intended load and circuits

k. **Orifice expansion tube**—used in an orifice tube system, controls refrigerant flow to the evaporator through a fixed orifice and provides low- and high-pressure protection for the system

l. **Power distribution module**—used to house relays, circuit breakers, fuses, and other control modules for the control of A/C circuits

m. **Pressure relief valve**—normally located on the receiver/dryer, designed to open to relieve pressure when refrigerant pressure reaches approximately 400 PSI

n. **Receiver/dryer**—removes moisture and particles from the liquid refrigerant, and stores refrigerant until needed in the system

o. **Relay**—controls current by rapidly switching current on and off

Note: There are many relays used in air conditioning circuits. These include: clutch, power, high-speed, and blower motor relays.

p. **Resistor block**—used to cause a voltage drop that controls the different speeds of the blower motor

q. **Sight glass**—located on the receiver/dryer or in-line, allows technician to detect multiple problems such as system contamination or low refrigerant level

r. **Surge diode**—used to protect electronic equipment from voltage spikes

s. **Thermostatic expansion valve**—used in an expansion valve system, controls refrigerant flow to the evaporator by comparing evaporator pressure and temperature

t. **Thermostatic switch**—used on systems with an expansion valve, senses temperature and keeps the evaporator from freezing

u. **Wiring**—connects components to the battery and/or each other

Objective 10

Types of engine block heaters and descriptions of their operations

Note: Engine block heaters are installed directly into the engine block in a location normally provided by the engine manufacturer. They are powered by either 110 or 220 volts AC, and are available in wattage up to 3,500 watts.

a. **Immersion block heater**—installed directly into the engine block, the warmed coolant circulates around the cylinder walls.

b. **Circulating tank heater**—heats coolant at the bottom of the engine block causing the heated coolant to rise where it is circulated back into the top of the block.

Note: To use an engine block heater, you must have access to an electrical outlet. Power cords normally come as part of the heater package; must be compatible with type and brand of heater.

c. **Diesel-fired coolant heater**—ignited by a glow pin, a flame is established and the glow pin shuts off. An integrated water pump circulates the water over the heat exchanger and heats the coolant, then circulates it through the engine block.

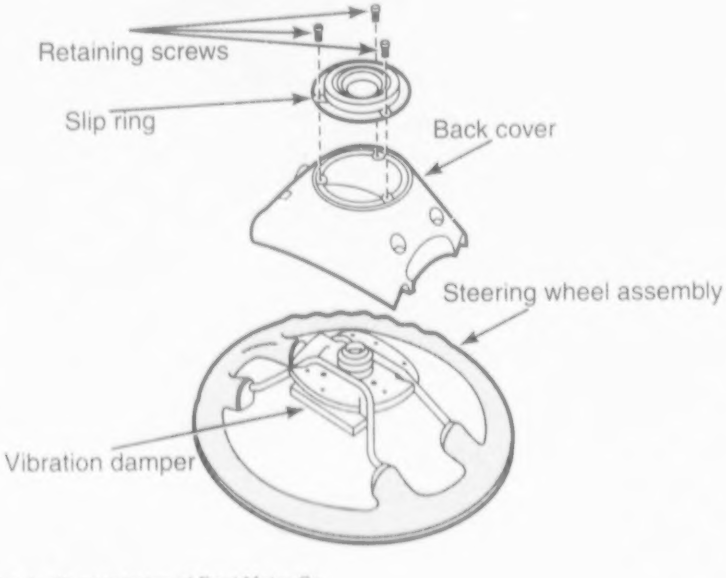
Student Supplement 1—How a Horn Operates

The horn is an electrical device that produces an audible sound to aid the driver in the safe operation of a vehicle. Most vehicles are equipped with a high-note and a low-note horn that is wired in series. The horn circuit is made of typical circuit devices. Its components are a switch (horn-button switch), relay, fuse, fusible link, related wiring, and a horn assembly.

On vehicles that do not have a relay, the horn-button switch is wired directly to the horn assembly. These horn system designs use low current demand horn assemblies because the horn-button switch cannot carry high current. When the vehicle operator presses on the horn-button switch it completes the circuit from the battery to the horn assembly (s). When the vehicle operator presses on the horn-button switch of a relay type horn system, the low current from the battery is fed to the relay unit that ultimately boosts the current needed for the heavy demand of the horn assembly(s).

The horn-button switch is commonly found on the steering wheel, but it may be part of a multifunction switch. Steering wheel mounted horn-button switches need sliding contacts to provide continuity for the horn control in all positions of the movable steering wheel.

Figure 1

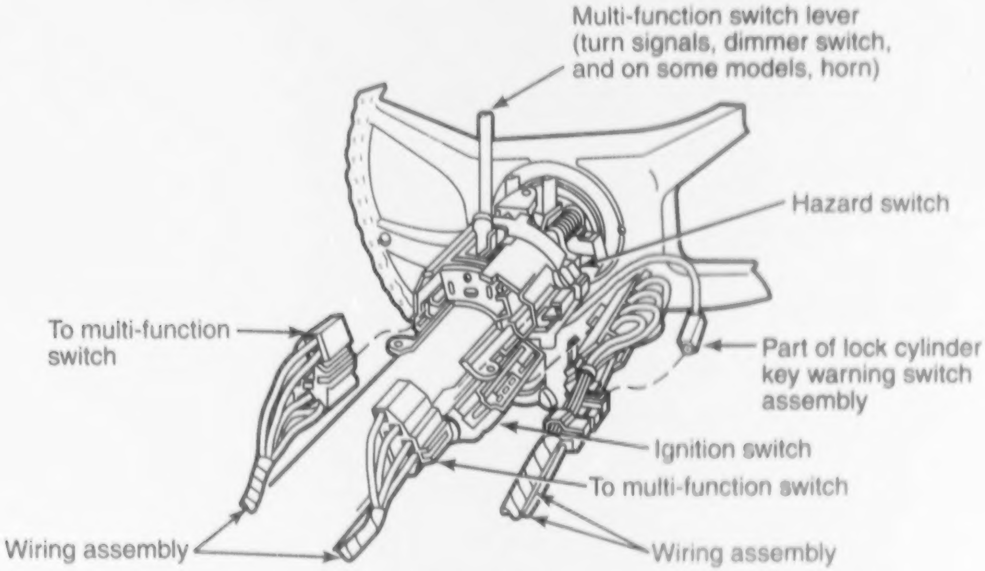


Used with permission of Ford Motor Co.

A horn-button switch that is part of a multifunction switch is usually operated by a push-button on the end of a lever.

Student Supplement 1

Figure 2

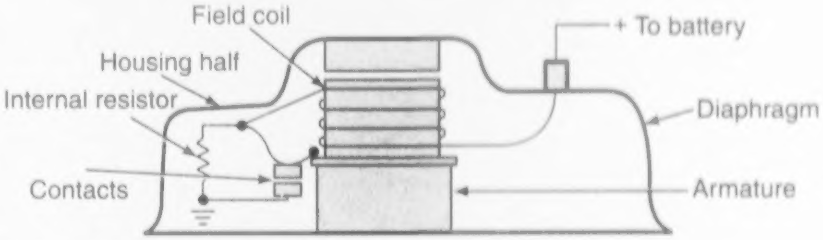

Multi-function switch lever
(turn signals, dimmer switch,
and on some models, horn)
Hazard switch
To multi-function
switch
Part of lock cylinder
key warning switch
assembly
Ignition switch
To multi-function switch
Wiring assembly
Wiring assembly

Used with permission of Ford Motor Co.

Most vehicles use relay windings grounded through the horn-button switch as a control device. The horn relay is supplied voltage from the positive battery terminal through a fusible link to the relay winding and contacts. Current flows to the relay which strengthens the relay core. The core attracts the relay armature, which closes the contacts and completes the horn circuit.

An electromagnet within the horn assembly is then energized. As the electromagnet pulls on the diaphragm within the assembly a set of contact points open, breaking the circuit. The diaphragm is released and the contact points close again, repeating its cycle several times per second. This rapid movement creates a column of vibrating air that produces the sound of the horn.

Figure 3


Field coil
+ To battery
Housing half
Internal resistor
Diaphragm
Contacts
Armature

Used with permission of Ford Motor Co.

One horn may have a slightly different pitch from another horn. Pitch is controlled by the number of times the diaphragm vibrates per second. Some horns have a pitch adjustment screw that allows for pitch control.

Student Supplement 2—Diagnosing Horn Problems

CONDITIONS	POSSIBLE CAUSES
Both horns do not operate (relay type)	Blown fuse or fusible link Open circuit or poor connection from the positive terminal of the battery to the relay Open circuit to relay control circuit Broken or worn wires Loose or poor connections along the circuit path Dirt or foreign matter on horn-button switch contacts or relay contacts Defective relay Open circuit or poor connection from relay to horn assembly Defective horn assembly ground wire Defective horns
One horn of a two-horn system does not operate (relay type)	Loose or dirty horn mounting Defective horn Improper contact adjustment Open circuit Loose or defective ground wire Corroded or dirty connectors

Student Supplement 2

Single horn does not operate (Non relay type)	Blown fuse Loose or defective ground wire Lose or dirty horn mounting Open circuit in horn-button switch Defective horn
Horn continuously operates (Relay type)	Stuck relay contacts Grounded wire from horn-button switch to horn assembly
Horn(s) continuously operate (Non relay type)	Defective horn-button switch
Incorrect tone	Improperly mounted horn assembly Improperly adjusted contacts Foreign material lodged in horn assembly Defective horn assembly

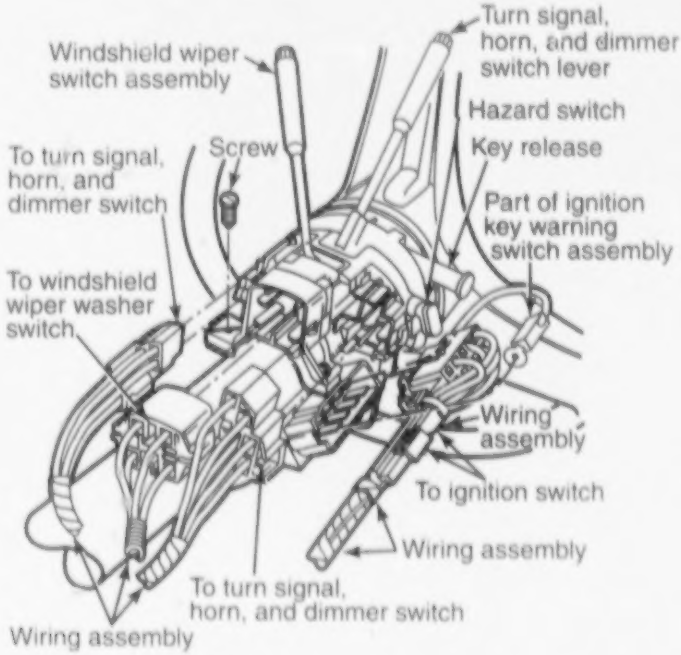
Student Supplement 3—How a Wiper Operates

Windshield wipers are electrical devices that remove water, snow, dirt, and other foreign materials from the windshield of a vehicle. A typical windshield wiper circuit is made up of common circuit devices; a switch, rheostat, fuse or circuit breaker, relay, connectors, and related wiring. It also includes a wiper motor assembly, wiper linkage, wiper arms, wiper blades, and a washer system.

The switch for the wiper system is usually a multi-position switch. By moving the switch to different positions a driver can adjust the wiper speed. The wiper switch controls the speed of the wiping action by directing current through a relay to different relay contacts within the wiper motor.

In addition to various speeds, many vehicles are equipped with an intermittent or interval feature. These systems usually have a solid-state module that operates the wiper motor to provide the proper delay. When a particular voltage signal is received by the module it opens and closes the ground circuit on the low-speed relay winding of the wiper motor assembly, providing an intermittent wiping action. On some wiper systems various resistors are connected to the wiper switch.

Figure 1

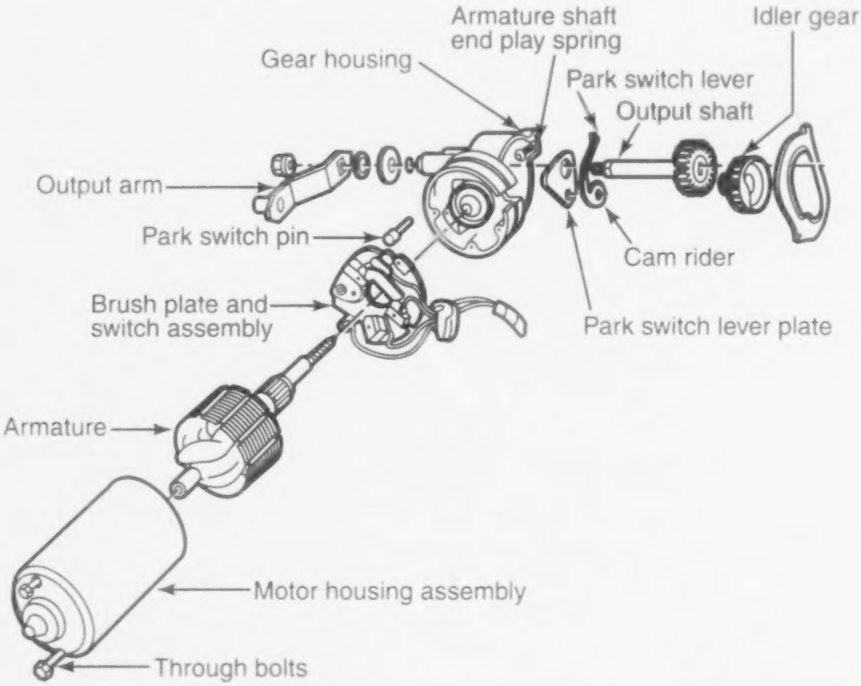

Windshield wiper switch assembly
Turn signal, horn, and dimmer switch lever
Hazard switch
To turn signal, horn, and dimmer switch
Screw
Key release
Part of ignition key warning switch assembly
To windshield wiper washer switch
Wiring assembly
To ignition switch
Wiring assembly
To turn signal, horn, and dimmer switch
Wiring assembly

Used with permission of Ford Motor Co.

When the wiper switch is in the on position, current flows through one set of switch contacts. This action grounds the relay contacts, completing the circuit to the wiper motor. Wiper motors may contain a series field coil, a shunt field coil, and a relay. If the wiper switch is in the low speed condition, the shunt coil is grounded and the motor turns at low speed.

Most vehicles use permanent magnets in place of field coils to operate the wiper motor. These magnetic fields control the placement of brushes (a low-speed and a high speed brush)on a commutator within the wiper motor. Some vehicles use two electromagnetic fields: a series field and a shunt field. The two field coils are wound in opposite of each other, resulting in opposing magnetic fields. How fast the motor will turn depends upon the strength of the total of these two magnetic fields.

Figure 2


Armature shaft end play spring
Idler gear
Gear housing
Park switch lever
Output shaft
Output arm
Park switch pin
Cam rider
Brush plate and switch assembly
Park switch lever plate
Armature
Motor housing assembly
Through bolts

As the wiper motor turns, its transmission changes the rotary motion into a back and forth wiping motion. The transmission is made up of gears, end housings, and a drive crank. A set of arms called the wiper linkage is connected to the wiper motor transmission at the drive crank. The drive crank transfers the back and forth motion to the wiper linkage, which transfers the motion to the wiper blades.

Located in the wiper motor assembly are park contacts. They supply current to the motor so that the motor will operate until the wipers reach the park position. In some vehicles a depressed park feature reverses the angle of rotation of the wiper after the wipers reach the normal park position. Circuitry for a depressed wiper system includes a second set of contacts in the park switch.

Student Supplement 4—Diagnosing Windshield Wiper Problems

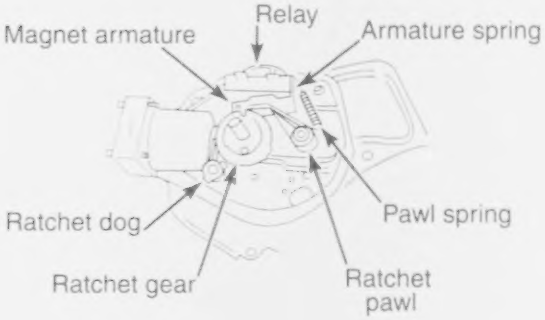
CONDITION	POSSIBLE CAUSES	CORRECTION
Wipers will not operate in any position	Defective fuse	Check and replace if required.
	Open circuit breaker	Check and replace if required.
	Poor ground at wiper motor	Attach jumper wire from wiper motor to car body. If motor works, check ground wire.
	Defective wiper switch	Test switch, replace if necessary.
	Switch not securely mounted	Tighten switch mounting.
	Bent or damaged motor linkage	Service as required.
	Defective motor	Perform motor current draw test. Repair and/or replace.
	Open wire or connector	Service as required.
Wipers will not operate in the low or intermittent position	Defective switch	Test switch. Repair or replace.
	Defective motor	Perform motor current-draw test for low speed. Repair and/or replace.
	Open wiring	Check circuits. Repair or replace.

CONDITION	POSSIBLE CAUSES	CORRECTION
Wipers will not operate in the low or intermittent position (continued)	Poor intermittent ground	Service as required and/or tighten attaching screws.
	Defective module	Replace interval module.
Wipers will not turn off	Defective motor	Perform parking test. Repair or replace.
	Defective switch	Perform parking test. Repair or replace.
	Defective wiring	Perform parking test. Repair or replace.
	Defective module	Replace module.
Wipers work only when in intermittent position	Open circuit	Service as required.
	Defective module	Replace module.
	Defective or dirty park contacts in wiper motor	Replace.
	Dirty connector	Clean connector. Service as required.
Sluggish operation	Binding linkage	Check for bent or damaged components.
	Defective wiper motor	Replace.

Student Supplement 5—How a Washer System Operates

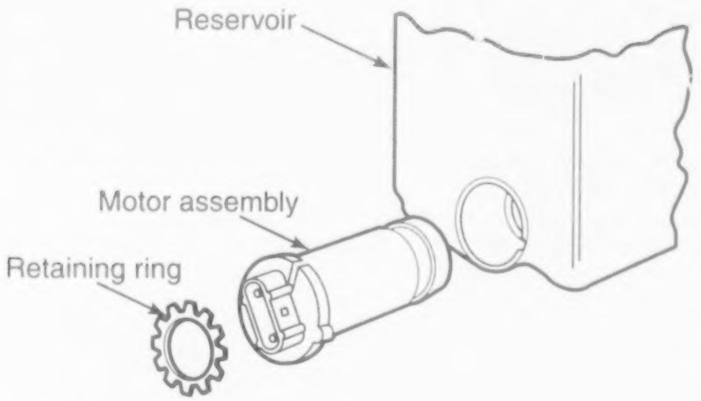
A washer system works in union with the windshield wiper blades to remove water, snow, dirt, and other foreign matter from the windshield. It uses a spray of washer fluid solution. The washer system components are a solvent reservoir, washer pump, rubber or plastic hoses, connections, and washer nozzles. The wiper switch activates the washer system. If the wiper system has an intermittent module, an override circuit in the module operates the wipers on low-speed for a specific length of time after the solution is sprayed on the windshields. The wipers will then return to their normal park position.

Figure 1—Rotary wash pump



When activated the washer fluid solution, located in the reservoir, is pumped through the hoses to nozzles located in front of the windshield. The washer pump is connected to the wiper motor but is "locked out" of the circuit until the wiper switch is placed in a hold position. When placed in a hold position the current flows through the pump solenoid to ground, completing the circuit.

Figure 2—Bellows washer pump



Used with permission of Ford Motor Co.

The washer pump may be a rotary pump or a bellows pump. A small electric motor spins an impeller that in turn forces the washer fluid solution through the hoses and nozzles. A rotary pump is usually located in the washer solution reservoir. A bellows type pump operates off of the wiper motor and is usually found off the wiper motor.

Student Supplement 6—How a Heating System Operates

The cab and sleeper systems obtain heat from the temperature of circulated engine coolant, which is then converted to hot air and blown into the cab. Hot coolant is delivered from the engine through the water valve to the heater core. The water valve, which controls the flow of coolant through the heater core, controls the temperature of the air leaving the ducting. Less coolant flowing through the heater core means a cooler temperature delivered to the cab. The water valve is operated in one of the three following ways: cable operated, thermostatically operated, or vacuum operated. It is vacuum operated on most heavy-duty trucks. Cold air from outside or inside is drawn through the heater core by the electrically driven blower motor, and distributed to the cab interior through ducting. A cable-controlled supply door, activated from the vehicle instrument panel or accessory dash panel by a sliding lever assembly, controls the amount of air drawn through the heater core. After releasing its heat, the coolant is pumped out through the heater core outlet where it's returned to the engine cooling system.

The heater core is a vital part of the system and is hard to access because of its location in the firewall of the vehicle. Over time, it can leak or become clogged by rust or other contaminants circulating through the engine coolant. That's one of the reasons why engine coolant should be changed according to manufacturer's specifications. When replacing a heater core, always leak test it before trying to install it so all your hard work will not have to be repeated if it leaks after installation.

The location of the electrically driven blower motor will vary with the make and model of the vehicle. Typically, the cab blower motor and housing are located underneath the right-hand dash panel, while the sleeper blower motor and housing are located behind the driver's seat. Both cab and sleeper blower motors are protected by either a fuse or circuit breaker located in the vehicle's fuse block panel.

Note: Although the sleeper heating system can be independent of the cab heating system, they operate in basically the same manner.

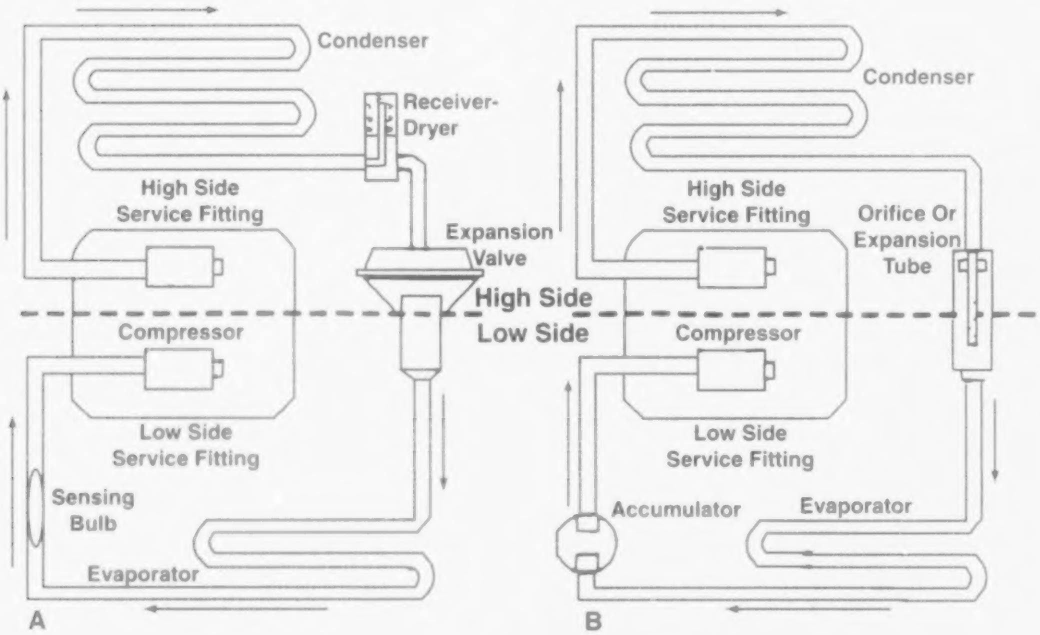
On newer vehicles, heating and cooling systems may be electronic and/or contained in one unit. This system utilizes heat sensors to maintain a specific temperature selected by the driver. These sensors send signals to a computer unit that simultaneously controls the water valve, blower motor, and supply door.

Student Supplement 7—How an Air-Conditioning System Operates

When we enter a vehicle on a hot day, we take it for granted that we can switch on the air-conditioner to cool the inside of the vehicle so we can ride more comfortably. Many of us often wonder how our ancestors were able to live without it in their homes and vehicles. Would you ever consider buying a vehicle, or operating a vehicle during the summer months without air-conditioning? Truck drivers spend a big portion of their lives traveling down the highway in their trucks. They travel across deserts where temperatures can reach over 110 degrees, and in the summer months temperatures can be in the 90's almost anywhere. Because truck drivers spend so much time on the road, they want to be as comfortable as possible. If a vehicle's air-conditioning fails, you can bet the driver will be looking for a shop that can fix it as quickly as possible.

Let's look at the two types of air-conditioning systems you might encounter and the basics of how they operate.

Figure 1—(A) Expansion valve system; (B) Orifice tube system


Condenser
Receiver-Dryer
High Side Service Fitting
Expansion Valve
High Side
Low Side
Compressor
Low Side Service Fitting
Sensing Bulb
Evaporator
A
Condenser
High Side Service Fitting
Orifice Or Expansion Tube
Compressor
Low Side Service Fitting
Accumulator
Evaporator
B

Note: The two systems basically operate in the same manner, and both systems use the same major components: compressor, condenser, and evaporator. The major differences between the two systems lie in the types of secondary components (receiver/dryer or accumulator, and expansion valve or orifice tube) and where they are located in the system.

Student Supplement 7

Expansion valve systems

The compressor receives refrigerant vapor from the evaporator and compresses it into a high-pressure vapor to allow the condenser to change the refrigerant back to a liquid state. The condenser, located in front of the radiator or mounted on the roof of the vehicle, turns the hot vapor (refrigerant) coming from the compressor into a warm liquid. From there, the liquid travels down line to the receiver/dryer where moisture and contaminants are removed and the liquid is stored until needed. When needed, the liquid flows to the thermostatic expansion valve which regulates the flow of the liquid into the evaporator. In the evaporator, the air passing over the evaporator loses its heat to the cooler surface of the core, causing the liquid to boil and vaporize. This action cools the air in the cab. The refrigerant then returns to the compressor as a vapor where the cycle starts again.

Orifice tube systems

The compressor receives refrigerant vapor from the evaporator and compresses it into a high-pressure vapor to allow the condenser to change the refrigerant back to a liquid state. The condenser, located in front of the radiator or mounted on the roof of the vehicle, turns the hot vapor (refrigerant) coming from the compressor into a warm liquid. From there, the liquid flows to the orifice tube which regulates the flow of the liquid into the evaporator through a fixed orifice. In the evaporator, the air passing over the evaporator loses its heat to the cooler surface of the core, causing the liquid to boil and vaporize. This action cools the air in the cab. The refrigerant vapor then flows to the accumulator which filters particles, removes moisture from the vapor, and prevents liquid from flowing into the compressor. The refrigerant vapor then returns to the compressor where the cycle starts again.

Electrical components

Note: Although the major portion of an air-conditioning system is not electrical in nature, there are electrical components of the system that require troubleshooting by a qualified technician. Here, we'll discuss the compressor and the cycling pressure switch.

The compressor, which in most cases is belt-driven, uses an electromagnetic clutch to engage the pulley to the compressor shaft when the clutch coil is energized. This allows the engine drive to be transferred through the clutch assembly to the A/C compressor shaft. When the electromagnetic clutch is on, or energized, the compressor operates to pump refrigerant vapor through the system. When the clutch is off, or deenergized, the compressor enters a freewheeling state since the compressor is not actually pumping under such a condition.

Another electrical component of the air-conditioning system is the thermostatic cycling pressure switch.

Note: Since the cycling pressure switch on orifice tube systems, and the binary switch on expansion value systems perform the same function, we will only address the cycling pressure switch in this supplement.

Located on the evaporator or accumulator (the binary switch is located on the receiver/dryer), the cycling pressure switch senses refrigerant pressure and temperature. Refrigerated pressure and temperature have a close relationship. High pressure means high temperature, and low pressure means low temperature. The cycling pressure switch is designed to control the evaporator temperature by cycling the compressor clutch off when the evaporator pressure (temperature) has increased. During moderate ambient temperatures between 60° and 80°F, the equalized pressures withing the charged system will close the electrical contacts of the cycling pressure switch. When the driver selects the A/C mode, electrical current is supplied to the compressor electromagnetic clutch coil to transfer engine power to the compressor assembly. With the compressor now operating, the A/C system evaporator pressure (temperature) is lowered to approximately 24 PSI at which point the cycling pressure switch will open and deenergize the compressor clutch coil. As the system equalizes, the switch contacts will close at approximately 45 PSI and reengage the compressor clutch coil. This continuous cycling action will continue to maintain system evaporator air temperature at approximately 33°F. If a low-charge condition exists at high ambient temperatures, poor cooling accompanied by rapid compressor cycling (on/off) will be noticed. The cycling pressure switch can fail in either the open or closed position.

Should replacement of the cycling pressure switch be required, it's not necessary to remove the refrigerant charge, since a Schrader valve is located in the fitting on the evaporator outlet.

Note: Closely resembling a tire valve, Schrader-type valves are usually located in the line from the compressor to the condenser, and in the line from the evaporator to the condenser to permit system checking on the low- and high-pressure ends of the system.

Objective 11

Assignment Sheet 1—Diagnose the Cause of Horn Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 1.	______

Basic Skills

Reading Critical Thinking

Introduction

Relays are found in most of today's horn circuits, however some vehicles do not have relays. In a vehicle that has a relay, current flows from the positive battery terminal through a fusible link to the relay windings and contacts. When the horn-button switch is in the closed position, the relay windings are grounded through the switch and the circuit is completed. On vehicles that do not have a relay, the current flows from the horn-button switch directly to the horn assembly.

Directions

Review and use the information found in the introduction to the assignment sheet, Student Supplement 1, *How a Horn Works*, and Student Supplement 2, *Diagnosing Horn Problems*, to answer the following questions. Write your answer in the bank provided.

_____ 1. Which of the following is **not** a possible cause for a horn system failing to operate on a vehicle with a relay?

a. Short circuit in horn-button switch
b. Broken or loose wires
c. Defective relay
d. Blown fuse

_____ 2. Which of the following is **not** a possible cause for a horn system failing to operate on a vehicle without a relay?

a. Open circuit in horn-button switch
b. Loose or dirty horn mounting
c. Defective relay
d. Dirty connectors

____ 3. Technician A says checking the circuit path for broken wires or loose connections is the first place to start when diagnosing horn problems. Technician B says it depends on whether or not the horn system has a relay. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. Which of the following is **not** a possible cause for continuous operation in a horn circuit with a relay?

a. Defective horn assembly
b. Grounded wire from horn-button switch to horn assembly
c. Blown fusible link
d. Stuck contacts

____ 5. Technician A says current flows from the battery through a fusible link to the relay winding and contacts on a non-relay type horn system. Technician B says current flows from the horn-button switch directly to the horn assembly. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. When a one-horn assembly does not operate correctly in a two-horn system which of the following may be the cause?

a. Defective relay
b. Blown fuse
c. Dirty relay contacts
d. Defective horn assembly

____ 7. On vehicles that do not have a relay, the current flows from the horn-button switch directly to the horn assembly. True or False?

a. True
b. False

____ 8. While visually inspecting the horn circuit, the Electrical Technician discovers a loose mounting. Which of the following problem(s) is **not** a result of the loose mounting?

a. Continuous operation
b. One horn of a two-horn system does not operate
c. Incorrect tone
d. Answers B and C

____ 9. While visually inspecting the horn circuit, the Electrical Technician discovers dirty relay contacts. Which of the following problem(s) could result from dirty relay contacts?

- a. Continuous operation
- b. Horns operate intermittently
- c. Incorrect tone
- d. All of the above

____ 10. Which of the following is **not** a possible cause for one horn not operating in a two-horn system without a relay?

- a. Blown fuse
- b. Loose or defective ground wire
- c. Open circuit in relay control circuit
- d. Defective horn assembly

Objective 12

Assignment Sheet 2—Diagnose the Cause of Wiper Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading

Critical Thinking

Introduction

When diagnosing the cause of wiper problems follow the path of the circuit. A poor ground or loose wiring is usually at fault. By checking the wiring, harnesses, connectors, and then components, a process is started by which the most common problems are eliminated.

The wiper motor, usually located close to the cowl of the vehicle, and the transmission for the wiper arms, usually located on the arm, are other possible causes when diagnosing problems with the wiper system. Bent gears and broken or damaged teeth of the wiper transmission are other common causes for wiper failure.

Directions

Review and use the information found in the introduction to the assignment sheet, Student Supplement 3, *How a Wiper Operates*, and Student Supplement 4, *Diagnosing Windsheld Wiper Problems*, to answer the following questions. Write your answer in the blank provided.

_____ 1. A vehicle has an open shunt coil in the wiper motor. Technician A says the problem can cause the wiper to operate at low-speed. Technician B says the problem will cause the wiper to operate all the time. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 2. Which of the following is **not** a possible cause for a sluggish wiper system?

a. Blown fuse
b. Bent linkage
c. Binding linkage
d. Defective wiper motor

_____ 3. Vehicle wipers will not shut off. Technician A says the problem is caused by open wiring. Technician B says the problem is caused by a defective module. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 4. Which of the following is **not** a possible cause for a wiper system that will not stop operating when in the park position?

a. Dirty connector
b. Open park circuit
c. Binding linkage
d. Defective wiper motor

_____ 5. Which of the following is **not** a possible cause for a wiper system which operates only in the intermittent position?

a. Open circuit
b. Defective module
c. Open park circuit
d. None of the above

_____ 6. A vehicle's wipers will not operate in any position. Technician A says the problem is caused by a defective wiper switch. Technician B says the problem is caused by a poor intermittent ground. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 7. A poor ground at the wiper motor is causing the wipers not to operate. To check for a poor ground Technician A says to connect a jumper wire from the wiper motor to the ground terminal of the battery. Technician B says to connect the jumper wire from the wiper switch to the wiper motor. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 8. Which of the following is **not** a possible cause for a wiper system that will not operate in any position?

a. Open circuit breaker
b. Defective wiper motor
c. Defective wiper switch
d. Open series coil

____ 9. A vehicle's wiper arms will not stop moving. Technician A says an open circuit is probably the problem. Technician B says a poor ground at the wiper motor is the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 10. Which of the following is **not** a possible cause for a wiper system which operates only in a low speed position?

a. Open circuit breaker
b. Defective wiper motor
c. Defective wiper switch
d. Poor intermittent ground wire

Objective 13

Assignment Sheet 3—Diagnose the Cause of Windshield Washer Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 4 of the 5 questions correctly per Answers to Assignment Sheet 3	______

Basic Skills

Reading

Critical Thinking

Introduction

When diagnosing an inoperative windshield washer system check the following possible causes.

- Insufficient washer fluid solution
- Blown fuse
- Broken wires
- Clogged screen at end of the reservoir cover hose
- Clogged washer nozzles
- Damaged, loose, or kinked hoses
- Loose or open circuit connection to washer pump or wiper switch
- Defective pump
- Defective wiper switch
- Defective pump valve
- Open circuit in pump solenoid coil

If the washer pump works continuously while wiper is operating, look for a defective wiper switch or grounded wire from pump to the wiper switch.

Assignment Sheet 3

Directions

Review and use the information found in the introduction to the assignment sheet, and Student Supplement 5, How a *Washer System Operates* to answer the following questions. Write your answer in the blank provided.

____ 1. Which of the following is **not** a possible cause for a washer system to operate continuously while wiper is operating?

a. Grounded wire
b. Defective wiper blade
c. Defective wiper switch
d. Open circuit

____ 2. Which of the following is **not** a possible cause for a washer system to operate continuously?

a. Blown fuse
b. Clogged washer nozzles
c. Defective wiper switch
d. Defective wiper motor

____ 3. Which of the following is a possible cause for a washer system to operate continuously?

a. Worn wiper blades
b. Clogged screen at end of the reservoir cover hose
c. Insufficient washer fluid solution
d. Open circuit connection to washer pump or wiper switch

____ 4. A voltmeter is used to test the washer pump motor. There is no voltage registering on the meter. Technician A says to replace the washer pump. Technician B says it could be a broken wire or poor connection to the fuse block and the washer pump connection. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B.

____ 5. The washer pump is operating but fluid is not reaching the windshields. Technician A says the hoses, nozzles and screen should be checked for loose, clogged, or binding. Technician B says the wiper intermittent modules are probably defective. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B.

Objective 14

Assignment Sheet 4—Diagnose the Cause of Heater Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 3 of the 4 questions correctly per Answers to Assignment Sheet 4	______

Basic Skills

Reading

Critical Thinking

Introduction

Vehicle heating systems are fairly simple in construction and operation, but some late-model heavy vehicles are equipped with combination heater/air-conditioner systems that are electronic. These systems automatically control the temperature in the cab/sleeper through the use of temperature sensors. A computer unit receives signals from the various sensors and makes adjustments to maintain a selected temperature. The computer unit controls the compressor, blower, water valve, and supply doors. Because of this, certain problems that arise could be linked to a component of the heating/air-conditioning system, or a malfunctioning computer unit may cause the problem.

The vehicle's thermostat also plays a role in the heating system. A malfunctioning thermostat or a thermostat rated at the wrong temperature, may not allow the engine to reach normal operating temperature. The temperature of the coolant flowing into the heater core will be below normal, therefore causing the air flowing into the vehicle to be at a lower temperature. This may cause the blower motor to run continuously because of the amount of time it would take to raise the temperature in the cab.

Directions

Review and use the information found in the introduction to the assignment sheet, and Student Supplement 6, *How a Heating System Operates* to answer the following questions. Write your answer in the blank provided.

____ 1. Before replacing the heater core, Technician A says you should accomplish a leak check to insure the heater core does not leak. Technician B says that accomplishing a leak check is not necessary unless the heater core leaks after installation. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. Technician A says that when the blower stops operating, the problem is probably a defective selector switch. Technician B says the first thing you should do is check for a blown fuse or circuit breaker. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. Technician A says the reason the blower will not change speeds when a different speed is selected, is probably because of a defective selector switch. Technician B says the problem is probably associated with a bad resistor. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. On an electronic system, Technician A says that the reason the blower is blowing cool air into the cab when a higher temperature is selected is because the water valve is not functioning properly. Technician B says the problem is probably associated with malfunctioning computer unit. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 15

Assignment Sheet 5—Diagnose the Cause of Air-Conditioning Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	_____
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 5	_____

Basic Skills

Reading

Critical Thinking

Directions

Review and use the information contained in the introduction to the assignments sheet and Student Supplement 7, *How an Air Conditioning System Operates* to answer the following questions. Write your answer in the blank provided.

____ 1. Technician A says that the air-conditioning compressor pulley is always belt-driven during engine operation. Therefore, the A/C system is always on unless switched off by the operator. Technician B says that although it is true that the pulley is usually belt-driven, no compressor operation results unless the electromagnetic clutch is energized. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. Technician A says that the function of the cycling pressure switch is to sense the refrigerant pressure (temperature) and to cycle the compressor on or off as necessary. Technician B says that it senses the refrigerant pressure (temperature) and only shuts the compressor off. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Assignment Sheet 5

____ 3. During moderate ambient temperatures, Technician A says that the cycling pressure switch contacts would be closed. Technician B says they would be open. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. Technician A says that if a low-charge condition exists in an A/C system, excessive cooling accompanied by a permanently engaged compressor will result. Technician B says that poor cooling accompanied by rapid compressor clutch cycling action will be noticeable at high ambient temperatures. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. Technician A says that the purpose of a current surge diode in the system wiring harness at the compressor is to prevent voltage spikes from damaging the cycling pressure switch. Technician B says that it is to protect the electromagnetic compressor clutch from a voltage overload causing rapid on/off cycling conditions. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. Technician A says that if a compressor fails to operate or engage, the first thing to check is voltage at the compressor coil. Technician B says that you would check for a blown fuse or circuit breaker. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. Technician A says that if voltage were observed at the compressor coil yet it fails to operate, the next step would be to check for a proper ground circuit. Technician B says that voltage at the compressor coil with no operation would confirm that a burned-out coil is the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 8. Technician A says that when an A/C system cycling pressure switch malfunctions, it may remain in either the open or the closed position. Technician B says that they always fail in the closed position. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 9. Technician A says that some A/C pressure sensing systems are equipped with an electrical limit switch that is used to disengage the compressor clutch should pressure reach a value of about 200 PSI. Technician B says that the high-pressure relief valve would disengage the compressor closer to 400 PSI. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 10. Although the A/C system compressor cut-in and cut-out pressure ranges will vary between systems, generally this will occur at the following pressures:

a. cut-out at 10 to 12 PSI; cut-in at 20 to 24 PSI
b. cut-out at 15 to 17 PSI; cut-in at 32 to 35 PSI
c. cut-out at 21 to 27 PSI; cut-in at 43 to 49 PSI
d. cut-out at 35 to 40 PSI; cut-in at 79 to 82 PSI

Objective 16

Job Sheet 1—Inspect, Test, Repair, and Replace the Components of a Horn Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

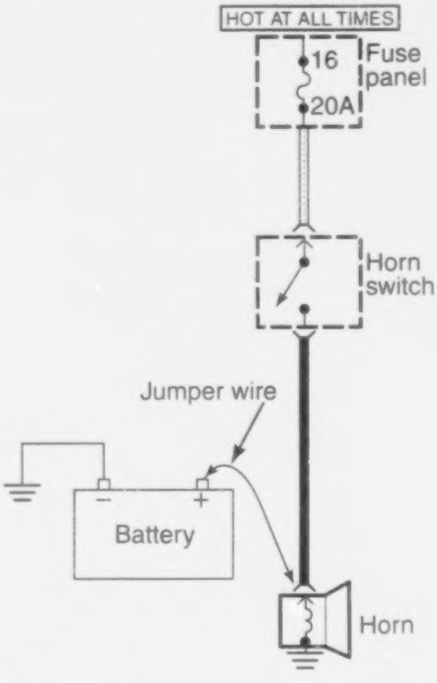
Warning: Consult the service manual and/or follow manufacturer's procedures for disabling the airbag system prior to troubleshooting or repairing horn components.

Horns should be inspected periodically or whenever the hood is opened for service. The horn needs service if one or more horns do not operate, the horn sounds continuously, or if the pitch of the horn needs to be adjusted. Visually inspecting the path of the circuit for loose connections, corrosion, dirt, and broken or worn wires will often save time and energy when diagnosing the cause of horn problems.

If the horn does not operate, check the fuse and fusible link to see if it is blown and replace if necessary. Some replacement fusible links come with connectors and some may need to be soldered in place. Inspect the ground wire to make sure it is clean and securely attached. Inspecting components of the horn circuit includes checking mounting bolts of the horn assembly to ensure they are tight and securely in place.

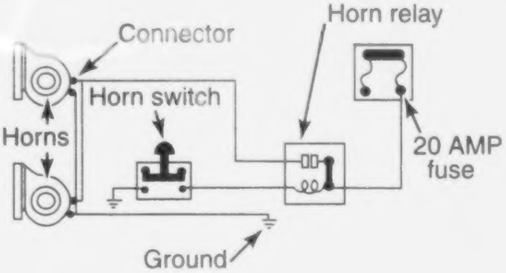
To test whether a horn assembly is inoperative, a voltmeter or test lamp and jumper wire may be used. On a vehicle without a relay, connect the jumper wire from the horn housing to the vehicle ground or the battery ground terminal.

Figure 1


HOT AT ALL TIMES
16
20A
Fuse panel
Horn switch
Jumper wire
Battery
Horn

On vehicles with a relay, connect a jumper wire from the horn relay to the vehicle ground.

Figure 2


Connector
Horn relay
Horn switch
Horns
20 AMP fuse
Ground

If the horn sounds, there is probably an open circuit in the relay control circuit. Look for a broken wire or loose connection along the path of the relay to the switch. Check all connections and the horn-button switch for dirt build-up on contacts. The steering wheel may need to be removed in order to check the contacts of the horn-button switch. Follow manufacturer's directions for removal

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of the steering wheel. The horn-button switch contacts may be cleaned with alcohol.

If the horn doesn't sound, check the current supply by placing the voltmeter at position 1 as shown in Figure 1. Check for loose connections and worn wires at the battery terminal and along the route of the current supply. If the current is available at the horn relay position, connect the voltmeter from the horn connection of the relay to the ground as shown in Figure 1, position 2. If current is not present at the horn relay position, the relay is probably defective and should be replaced.

When a system has two horns, testing procedures require that both horns be tested. If one horn is inoperable, check the ground connection of that horn assembly. If voltage is present at the horn assembly connection, replace that horn assembly. If the horn sounds, remove the horn and inspect the horn mounting. Clean the housing surfaces and replace the horn unit.

Sometimes a horn may not sound due to improper contact adjustment. The amount of gap between the contacts sets the amount of current that is being drawn by the horn. If the gap is too wide or if dirt or foreign matter is obstructing the current, the horn may not sound. To adjust the horn assembly, turn the adjusting screw counterclockwise about one quarter turn. If the horn sounds use an ammeter to determine the amount of current being drawn by the horn. If the current is incorrect, it may continue to be adjusted until it is within manufacturer's specifications as described in the service manual.

When a horn operates continuously, the relay contacts may be stuck in the closed position or the relay may be operated by a grounded wire. Always remove the wire connections to the horn assembly units when the horn is operating continuously to prevent damage to the horn assemblies. Locate and repair the wire. Check for a grounded wire along the path of the horn circuit using procedures learned in previous units for checking for a grounded wire. If testing proves that the wires are operating correctly, the relay contacts are stuck and should be replaced.

Incorrect tone is usually just a matter of adjusting the adjustment screw within manufacturer's specifications. However, the horn mounting may be causing the problem. Check for loose mounting. Check to see if the horn assembly is touching any other part of the vehicle. Reposition the horn if mounted incorrectly.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Jumper wire
- Shop towel
- Safety glasses
- Voltmeter or test light

Job Sheet 1

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and material to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 1

1252

1251

Objective 17

Job Sheet 2—Inspect, Test, Repair, and Replace the Components of Wiper Circuits

Name ________________________ Attempt Number ______

Date ________________________ Overall Rating ______

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Visually inspecting the path of the circuit for loose connections, corrosion, dirt, and broken or worn wires will often save time and energy when diagnosing the cause of intermittent wiper problems. Compare the problem of the wiper system to possible causes as shown in Student Supplement 4.

When the wiper system does not work, start testing procedures at the wiper motor. Before testing, make sure the wiper motor is mounted correctly and the fuses or circuit breakers are good. Check to make sure power is reaching the motor. If power is not reaching the motor, test the wiper switch. If power is reaching the motor and the ground is good, the wiper motor or gear box is defective. If power is reaching the motor, check for wiper motor current draw and resistance using methods learned in previous units.

Always refer to the appropriate service manual for exact procedure when servicing windshield wiper systems.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Jumper wire
- Ohmmeter
- Shop towel
- Safety glasses
- Voltmeter or test light

Job Sheet 2

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

Objective 18

Job Sheet 3—Inspect, Test, Repair, and Replace Intermittent (Pulsing) Wiper Controls

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Wiper systems should be inspected periodically or whenever the hood is opened for service. The intermittent wiper system needs service if they do not operate or if the operation is slow or sluggish. Visually inspecting the path of the circuit for loose connections, corrosion, dirt, and broken or worn wires will often save time and energy when diagnosing the cause of intermittent wiper problems.

Compare the problem of the wiper system to possible causes as shown in Student Supplement 4. Check wiper system components by testing the wiper motor, the wiper switch, connectors, wiper linkage, and intermittent module. If defective, replace or service as needed.

Use methods you have learned in previous job sheets to inspect and test common electrical components of the intermittent wiper systems. Always refer to the manufacturer's service manual for testing procedures and replacement specifications.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Jumper wire
- Ohmmeter
- Shop towel
- Safety glasses
- Voltmeter or test light

Job Sheet 3

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________________

Address ________________________

Phone # ________________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ________________________

Customer Address ________________________

Customer Phone # ________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________________

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Services/repairs made: ________________________

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LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________________ Date ____________

Technician ____________

Supervisor ____________

Objective 19

Job Sheet 4—Inspect, Test, Repair, and Replace the Components of a Windshield Washer Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

The washer fluid reservoir should always be checked for insufficient fluid whenever the hood is open. The hoses, wires, connectors, and nozzles should be visually inspected for obstructions, kinks, loose connections or damage. Visually inspecting the path of the circuit for loose connections, corrosion, dirt, and broken or worn wires will often save time and energy when diagnosing the cause of windshield washer problems.

Check the voltage on the washer pump motor using a voltmeter or a test light. If no voltage, look for a broken wire or loose connector. If voltage, connect a jumper wire to the washer pump. If the washer pump motor works, the wiper and/or washer switch is defective and should be replaced. If the washer pump motor does not work, it is defective and must be replaced.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Jumper wire
- Shop towel
- Safety glasses
- Voltmeter and/or test light

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Job Sheet 4

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________________

Technician ____________________

Supervisor ____________________

Objective 20

Job Sheet 5—Inspect, Test, Repair, and Replace the Components of a Heater Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Visually inspecting the path of the circuit for loose connections, corrosion, dirt and broken or worn wires will often save time and energy when diagnosing the cause of heating problems. Problems vary with the type of system being repaired. Combination heater/air-conditioners that are electronically controlled have more electrical circuits to diagnose than do older type liquid-cooled systems that have manual controls. Determining what type system you have is critical.

When the heating system does not work, start testing procedures at the battery. Before testing, make sure the fuses or circuit breakers are good. Check to make sure power is reaching the blower motor. If power is not reaching the motor, test the fan switch. Since the fan has more than one speed, speeds other than "high" will show a voltage drop. You can test the motor directly by using a jumper wire and bypassing the fan switch. Test the blower motor ground circuit from the ground terminal to the chassis ground.

Always refer to the appropriate service manual for exact procedure when servicing heating systems.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility.
- Wheel chocks
- Volt-Ohm meter
- Jumper wire
- Safety glasses
- Test light

Job Sheet 5

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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2260

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 21

Job Sheet 6—Inspect, Test, Repair, and Replace the Components of an Air-Conditioning Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

It's important to remember that there are two different types of air-conditioning systems: the expansion valve system and the orifice tube system. The first step in any diagnosis is to determine which type of system the vehicle is using. Although basically they work in the same manner and use the same major components, there are components unique to each system (see Student Supplement 7 for a description of the two systems).

When the air-conditioning system doesn't work, first try to determine which component is not functioning properly and then refer to the service manual for that particular component. If a component doesn't work, that doesn't mean it's defective and not functioning. The malfunction may be related to a switch that isn't sending the right signal or a valve that's not opening or closing properly. There are numerous switches and valves in air-conditioning systems that are electrically operated, so a comprehensive troubleshooting guide would be most helpful.

Always refer to the appropriate service manual for exact procedure when servicing air-conditioning systems.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job-ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Volt-Ohm meter
- Jumper wire
- Test light
- Safety glasses

Job Sheet 6

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 6

Objective 22

Job Sheet 7—Inspect, Test, Repair, and Replace the Components of an Engine Block Heater

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are follows	______
• Service manual is used property	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Engine block heaters are normally made for specific engines and are manufactured by several companies. They are used to heat engine coolant to aid in starting and reduce wear on the engine when ambient temperatures are low.

There are few parts to an engine block heater that can be serviced. When an engine block heater does not work, start testing procedures with the power cord. Check for continuity using a volt-ohm meter. If the power cord tests okay, use a volt-ohm meter to check for continuity in the heating element. If the element tests bad, the block heater will have to be replaced.

Always refer to the appropriate service manual or manufacturer's documentation for exact procedure when servicing engine block heaters.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Volt-Ohm meter
- Container (for engine refrigerant)
- Safety glasses

Note: Procedures vary with the vehicle. Always check the procedure in the service manual and the manufacturer's documentation before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job sheet when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 7

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Unit 11 Miscellaneous Electrical Accessories

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Objective Sheet

Unit Objective

After completing this unit, the student should be able to diagnose the cause of power window, electric door lock, radio reception, heated, lighted, and electrically operated mirror problems, the airbag warning light staying on or flashing, and inspect, test, and replace the parts of a power window, an electric door lock, an anti-theft system, a sound system, audio system components, an airbag system, a cigar lighter/auxiliary power outlet, a clock, and remove and reinstall audio system components. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Label the parts of a power window.
2. Match the names of the parts of a power window to descriptions of their functions.
3. Match the names of the parts of a heated, lighted, and electrically operated mirror to descriptions of their functions.
4. Label the parts of an electric door lock.
5. Match the names of the parts of an electrical door lock to descriptions of their functions.
6. Label the parts of a keyless and remote lock/unlock device.
7. Match the names of the parts of a keyless and remote lock/unlock device to descriptions of their functions.
8. Match the names of the parts of an anti-theft system to descriptions of their functions.
9. Label the parts of a sound system.
10. Match the names of the parts of a sound system to descriptions of their functions.
11. Label the parts of an airbag system.
12. Match the names of the parts of an airbag system to descriptions of their functions.
13. List what steps one should take to prevent the accidental deployment of an airbag.
14. Diagnose the cause of power window problems. (Assignment Sheet 1)

Objective Sheet

15. Diagnose the cause of heated, lighted, and electrically operated mirror problems. (Assignment Sheet 2)

16. Diagnose the cause of electric door lock problems. (Assignment Sheet 3)

17. Diagnose the cause of radio reception problems. (Assignment Sheet 4)

18. Diagnose the cause(s) of the airbag light staying on or flashing. (Assignment Sheet 5)

19. Inspect, test, repair, and replace the parts of a power window. (Job Sheet 1)

20. Inspect, test, repair, and replace the parts of a heated, lighted, and electrically operated mirror. (Job Sheet 2)

21. Inspect, test, repair, and replace the parts of an electric door lock. (Job Sheet 3)

22. Inspect, test, repair, and replace the parts of anti-theft systems. (Job Sheet 4)

23. Inspect, test, repair, and replace the parts of a sound system. (Job Sheet 5)

24. Remove and reinstall audio system components (unit). (Job Sheet 6)

25. Inspect, test, repair, and replace the parts of an airbag system. (Job Sheet 7)

26. Inspect, test, repair, and replace the parts of a cigar lighter/auxiliary power outlet. (Job Sheet 8)

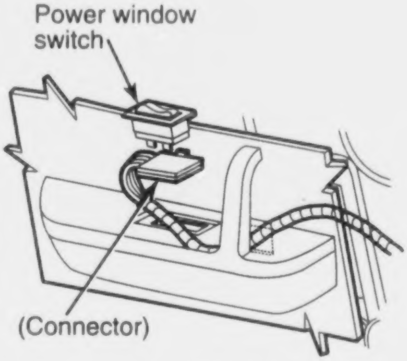
27. Inspect, test, repair, and replace the parts of a clock. (Job Sheet 9)

Information Sheet

Objective 1

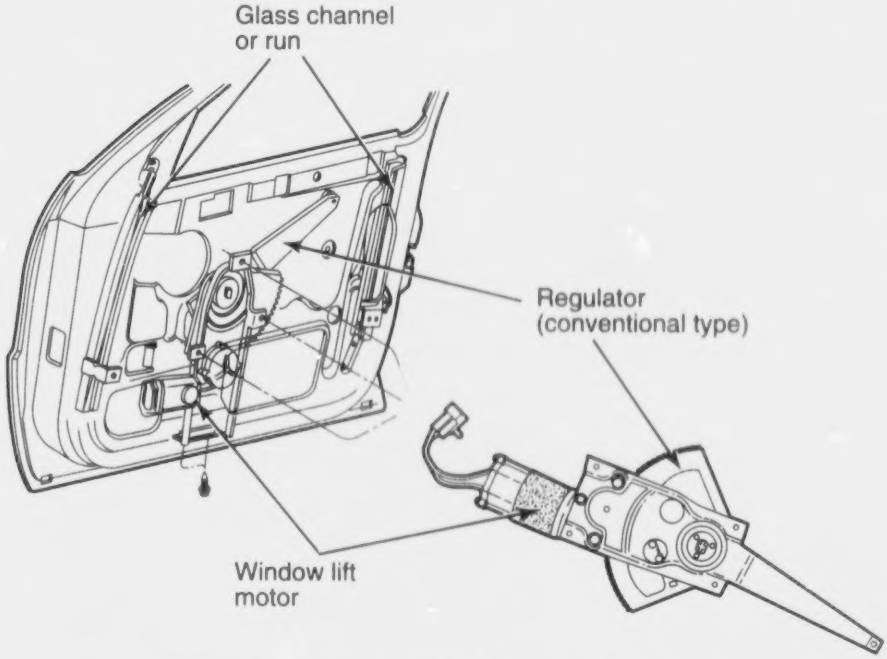
Parts of a power window

Figure 1


Power window switch
(Connector)

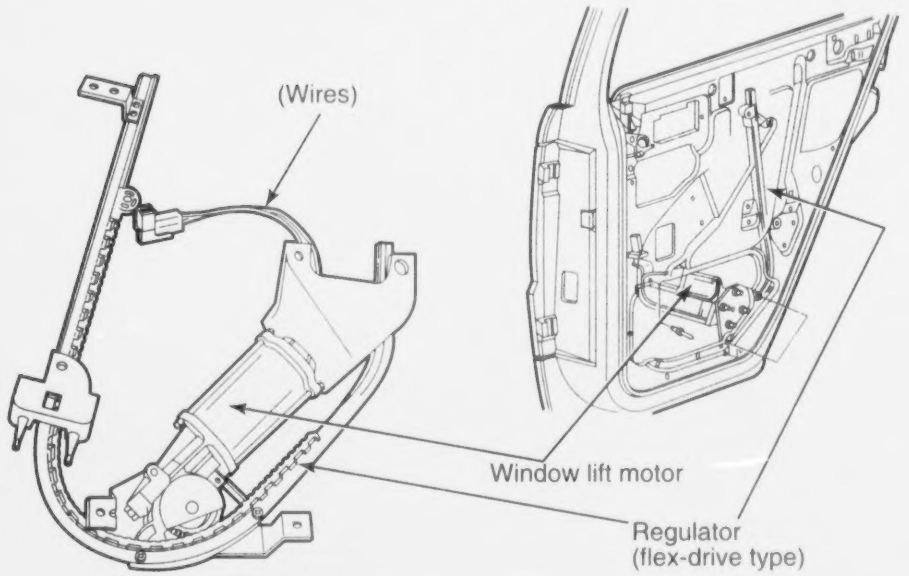
Used with permission of DaimlerChrysler Corp.

Figure 2


Glass channel or run
Regulator (conventional type)
Window lift motor

Used with permission of DaimlerChrysler Corp.

Figure 3



Used with permission of DaimlerChrysler Corp.

Objective 2

Parts of a power window and descriptions of their functions

Note: For a conventional window, the window glass disappears in the lowered position into a cavity in the vehicle door. In most vehicles, controls near the driver's seat can be used to raise or lower any of the operable windows from a master switch panel. Switches at passenger positions control only the window near that seat. The driver's control panel may include additional features, such as the ability to lower the driver's window with one touch of the switch or control of other windows by the driver only.

a. **Glass channel (run)**—guides the movement of the window in its frame

b. **Power window switch**—closes the circuit between the power source and the motor, and controls the direction of current flow

Note: Generally there is a switch at each side window position to allow control of that window. Most switches have three positions: one for opening, one for closing, and a neutral position. In the neutral position, the circuit is open and there is no current flow. Moving the switch to the open position causes the motor to rotate in a direction that will lower or open the window. Moving the switch to the close position reverses the direction of electrical flow, changing the polarity of the motor and causing it to rotate in the opposite direction. Switches are spring-loaded to the neutral position so that the switch must be held in position to operate the window. Some driver's window switches offer a one-shot operation so that quickly positioning the switch to the open position and releasing it will lower the window completely. A master control panel is located at the driver's seat, on the armrest, door, dash, or a console.

The master switch panel allows the driver to control each window. Frequently, the master panel also has a lock-out switch to prevent operation of passenger-side switches.

c. **Regulator (linkage)**—transmits mechanical force from the motor to raise and lower the window depending on the direction of motor rotation

d. **Window lift motor**—moves the drive component of the regulator to reposition the window glass, depending on the polarity of the supply voltage

Note: Each power window has a motor. The rotary output of the motor moves the regulator drive mechanism, such as a gear or a flexible belt, for that particular window. The motor output shaft is generally a gear that meshes with the regulator drive mechanism.

Objective 3

Parts of a heated, lighted, and electrically operated mirror and descriptions of their functions

Note: The power mirror circuit is generally an independent circuit used exclusively for adjusting the exterior mirror(s). Some vehicles have separate circuits for each exterior mirror; others use one set of controls with a switch to choose between the mirrors. Mirror light circuits are powered through the headlight switch and lights are turned on when the headlight switch is in the "On" or "Park" position. Heated mirror circuit elements are a separate circuit from the mirror positioning circuit and consist of resistors that produce heat in relation to the amount of current flowing through them.

a. **Heated mirror grid (element)**—heats the surface of the mirror by resisting the flow of current through the grid wires

b. **Heated mirror switch**—when closed, allows voltage to be applied to both mirrors and to the light indicating activation

c. **Motor (drive unit)**—an integrated unit controlling both the horizontal and vertical movement of the mirror glass

Note: Mekra mirrors consist of an upper rectangular (flat) mirror, and a lower square (convex) mirror. They contain dual motors equipped with a clutch to prevent damage in case of binding.

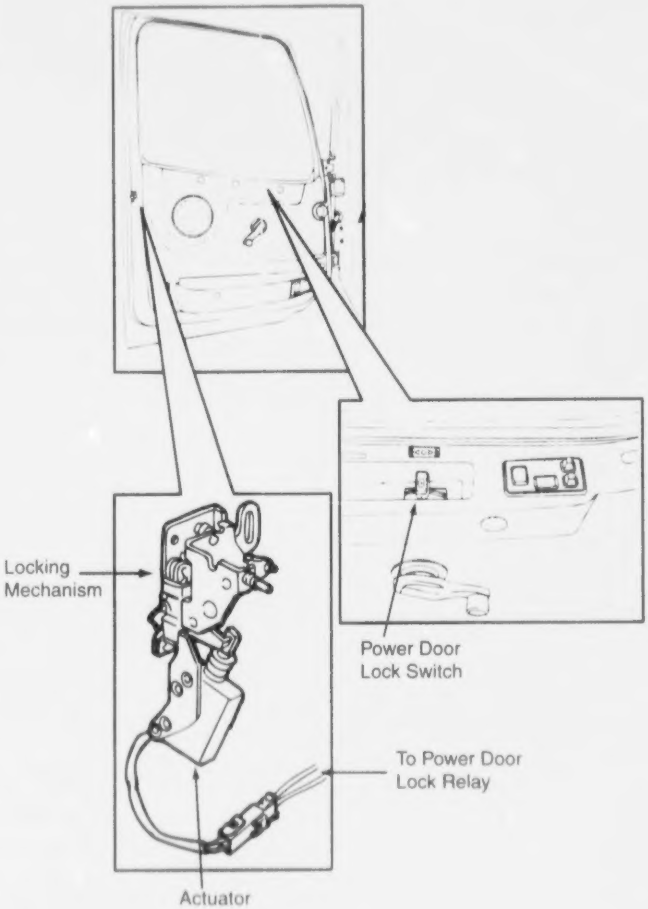
d. **Power mirror switch**—opens or closes the circuit to control the flow of current to the motors and the direction of current flow to determine motor polarity

Note: Most exterior mirrors use a joystick type switch. The four switch positions consist of two pairs, one for vertical control and one for horizontal control. With some designs, the joystick can be rotated clockwise or counterclockwise to select either the left or right exterior mirror. Other mirrors use four push button switches to control the mirror positioning and a rocker switch or paddle (lever) switch to choose the left or right mirror.

Objective 4

Parts of an electric door lock

Figure 4



Objective 5

Parts of an electric door lock and descriptions of their functions

Note: Most vehicles use a slide switch on each door to manually engage a mechanical lock. (Some older models use a stem rod that protrudes from the body of the door.) Many vehicles are additionally equipped with electrically operated door locks. These power locks provide another means of controlling the locks; the mechanical locks provide a safety backup should the power system fail. Most of the mechanical portions of the two systems use the same parts. The manual and power locks may use different actuator linkages.

a. **Actuator**—moves the locking mechanism between the engaged and disengaged positions, using either a motor or a solenoid

   - Door lock motors are normally reversible motors. Brushes at each end of the armature allow the motor to rotate in either direction depending on the direction of current flow. Rotation in one direction drives a linkage to engage the lock, while rotation in the other direction causes the linkage to disengage the lock.

- In solenoid designs, the plunger of the solenoid connects directly to the locking mechanism. When a solenoid is energized, a magnetic field is created and the plunger shifts position, moving the locking mechanism. The door is locked when the plunger is extended and unlocked when it is retracted.

  Note: Each door generally has one motor or solenoid. Many vehicles use motors for the door locks and solenoids for releasing components that have electrical locks or latches.

b. **Locking mechanism**—when engaged, prevents the door latch from moving so that the door cannot be opened using the exterior (and often also the interior) door handle

Note: The door latch is the primary means of holding the door closed in its frame. The door lock prevents the latch from moving from the closed position. As long as the locking mechanism is engaged, the doors cannot be opened by the use of the exterior or interior handles. The locks must first be disengaged, although some vehicles allow the locking mechanism to be automatically disengaged when the interior handle is opened.

c. **Power door lock relay**—uses an electromagnetic coil to control the direction of current flow to the motors or solenoids and to allow control of multiple circuits from one switch

Note: Actuating the door lock switch applies power to the relay coil. The circuit generally contains two relays: one for the locking subcircuit and one for the unlocking subcircuit. With the switch in the LOCK position, the energized coils in the relays shift between one of two positions. Current flows through the locking relay to each of the motors or solenoids to engage the locking mechanism. The ground leg of the circuit runs through the unlocking relay. With the switch in the UNLOCK position, the relay coils energize and shift to the opposite position, allowing current to flow in the opposite direction. This reverses the direction of movement in the motors or solenoids, while current flows back through the locking relay to ground. Often the locking and unlocking relays are one integrated module.

d. **Power door lock switch**—opens or closes the lock-engaging or disengaging circuit to control the flow of current to the lock motors or solenoids

Note: The switch opens or closes the circuit to the actuator (motor or solenoid) and controls the direction of current flow. Current flow in one direction causes the actuator to engage the lock, while flow in the other direction disengages the lock. Controls are generally provided at each door. The switch is usually a slide switch or push button near the door handle or in a console. It may be a stem knob in the door above the latching mechanism. The switch is spring-loaded to a neutral position. Moving the switch to one extreme position locks the doors, while moving it to the other extreme unlocks the door. However, some push button and similar switches simply reverse current flow on each actuation.

Objective 6

Parts of a keyless and remote lock/unlock device

Figure 5

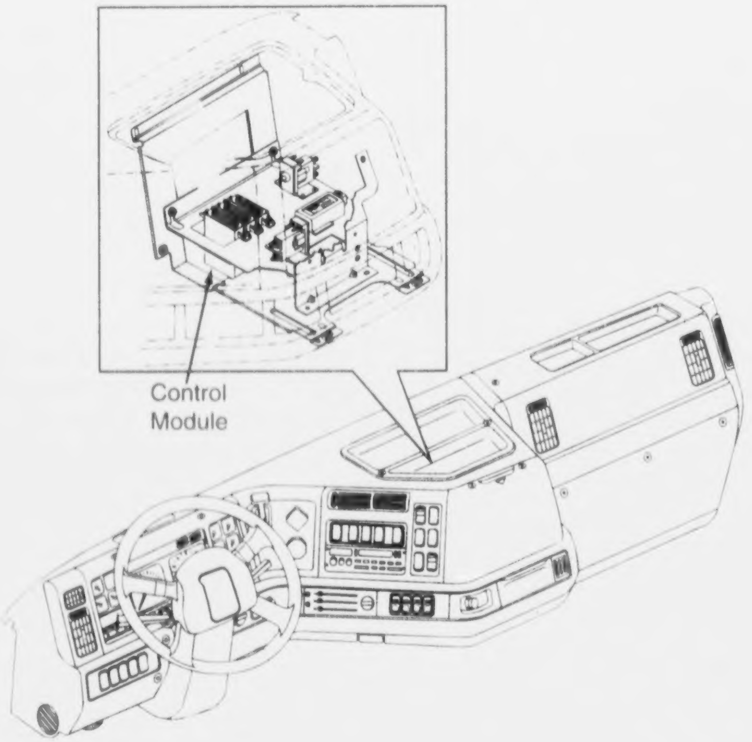
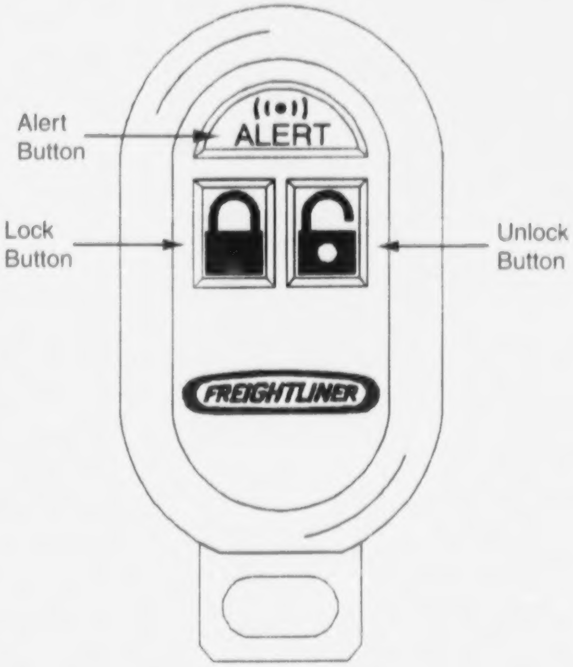


Figure 6—Signal Input Device



Courtesy of Freightliner LLC

Objective 7

Parts of a keyless and remote lock/unlock device and descriptions of their functions

Note: Two distinct door lock designs can be classed as keyless: electronic keypads and radio transmitters. The first type provides a numbered keypad near the exterior door handle of the driver's door. A person can lock the doors using the internal door lock switch or by using the keypad and can unlock the door by punching in a code on the keypad. Remote systems use a small radio transmitter to send a signal to a receiver in the door lock circuit to lock or unlock the doors.

a. **Control module**—receives input signals, validates those signals against stored signal information, and generates an electrical signal to engage or disengage the power lock

Note: The control module receives signals from the signal input device and processes those signals if they match the signal pattern stored in the control module memory. For example, a code from a keypad would have to match the number sequence that has been previously entered into the control module memory. For remote systems, the signal must be the proper radio frequency. If the signal matches the parameters, then the control module will respond to the command and generate an electrical pulse along the appropriate circuit.

b. **Power lock circuit**—engages or disengages the locking mechanism in response to electrical current from the control module

c. **Signal input device**—generates a signal on a dedicated frequency and sends it to the control module

Note: Pressing the buttons on the input devices produces electrical impulses that are carried to the control module by wires in keypad systems and by radio waves in remote systems. Most keypads have five buttons, each with two digits such as 1/2, 3/4, 5/6, 7/8, and 9/0. The unlock code signal is normally five digits, with additional functions available once the code is entered. Once the system has been activated, it will process other codes that are entered within a few seconds of the entry code. A control module, often located in the dash, contains a radio receiver tuned to the frequency of the transmitter. Receipt of a given signal, such as the unlock signal, causes the module to send an electrical pulse to the power lock system that will close the unlocking circuit.

Objective 8

Parts of an anti-theft system and descriptions of their functions

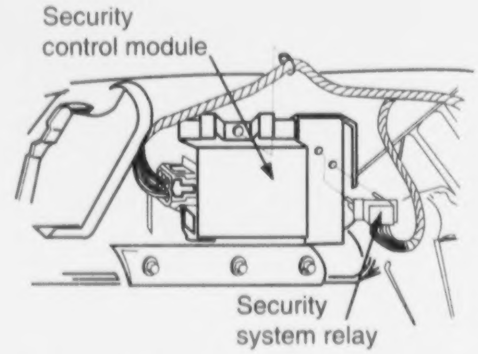
Note: Two approaches to reducing truck theft using on-vehicle equipment include (1) deterrents that produce audible and/or visual alarms, or (2) safeguards which make the vehicle inoperable. Many vehicles have both types of systems. Either type can involve the vehicle's electrical system or electronic components. Deterrents may be visual alarms, such as flashing taillights and parking lights, or audible alarms, such as sounding the horn. Most vehicle manufacturer's systems use existing circuits to produce alarm signals, such as having the headlights and taillights flash and the horn sound. Vehicles with voice alert systems may have a spoken warning. Safeguards prevent the vehicle from being driven if the anti-theft system is not properly disarmed. They often disable the starting system, ignition switch circuit, or the fuel system. In some systems, an unauthorized entry with the anti-theft system enabled will activate the disabling circuit. With others, an improper attempt to start the truck, such as by hot-wiring, will disable the circuit.

a. **Activation controls**—arm and disarm the system

Note: An armed system is one that is activated. It will sound an alarm or make the vehicle inoperable if the system is not properly disarmed. A system that is disarmed will not engage any of the alarm or theft-deterrent features. Many systems arm automatically when the doors are closed and locked after the engine has been turned off. In some systems, arming occurs only when the doors are locked using the key in the door key cylinder or locked by using a remote keyless device (transmitter). Using the key in the door key cylinder or a remote keyless device disarms most systems.

b. **Security control module**—detects a change in electrical condition (a signal from a circuit that has closed or a loss of signal from a circuit that has opened) and activates one or more alarms (deterrents) or engages a disabling system (safeguard)

Figure 7



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c. **Security system relay**—provides electrical control of system components in response to conditions

Note: The most common system relay is the alarm relay. The alarm relay usually connects to all of the sensors. Any disruption of a sensor circuit causes the relay to close the alarm switch. Specific portions of the system, such as the door jamb, ignition switch circuit, and motion sensors, may also have relays.

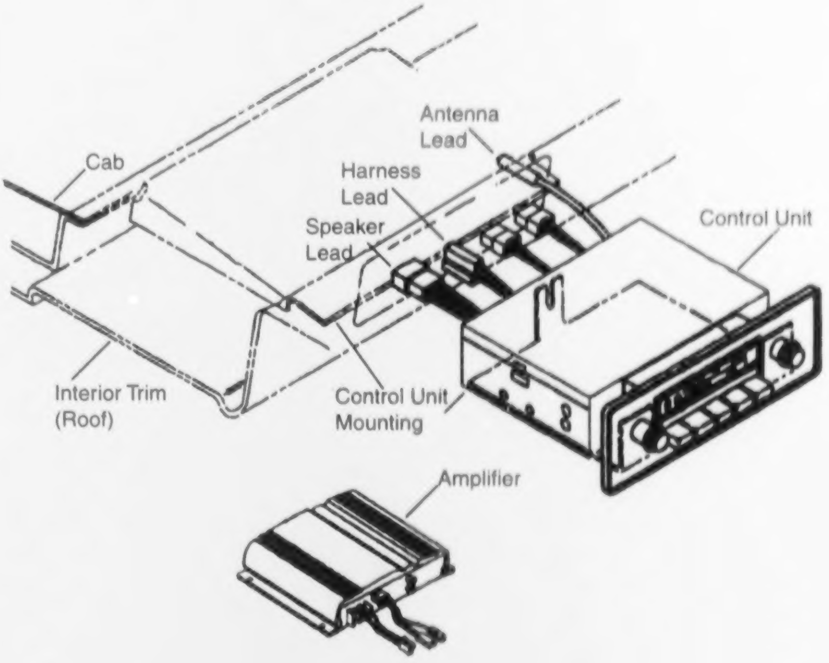
d. **Security system sensors**—monitors vehicle components and signals the security control module of an unauthorized intrusion

Note: Anti-theft systems commonly include multiple sensors, such as the ignition switch, hood switch, door ajar switch, and door key cylinder switch. Arming the system activates the sensors. Most sensors are electrical switches that are powered when the system is armed. They may be normally open or normally closed. An unauthorized intrusion causes the switch to move from its normal position. Some anti-theft systems use electromagnetic wave sensors, such as sensors that are sensitive to infrared light.

Objective 9

Parts of a sound system

Figure 8



Courtesy of Freightliner LLC

Objective 10

Parts of a sound system and descriptions of their functions

Note: Sound system equipment may range from an AM radio with a single speaker to audio systems with AM/FM radios, cassette players, compact disc (CD) players, graphic equalizers and multiple-CD changers. Speaker arrangements vary. The simplest arrangement uses a single speaker in the dash. Other layouts may include speakers in the doors, behind the rear seats, in the seats themselves, and in other locations.

a. **Amplifier**—increases the power of received signals from the control unit and outputs them to speakers

   Note: The signal received by the **antenna** is fairly weak. The amplifier increases the signals as they are sent to the **speakers**. A sound system may have one or more amplifiers, depending on the components included (radio, cassette player, compact disc player).

b. **Antenna** — receives AM and FM radio signals from all directions that are broadcast from transmitters

   Note: Fixed antennas are commonly mounted in the windshield or extend from the top of a cab.

c. **Antenna lead**—carries radio signals from the antenna to the radio

Note: The antenna is a shielded coaxial cable. The shielding protects the received signal, which is fairly weak, from static-causing interference from nearby wires. Such interference is called radio frequency interference (RFI).

d. **Control unit**—"demodulates" the received radio signals and provides for user selection of sound system functions

Note: A radio receiver in the control unit basically reverses the modulation of the AM or FM signal received so that the sound can be reproduced. The control unit also allows the user to control the functions of the sound system. For example, controls allow the user to turn the power on and off, adjust the volume, tune the radio, change the tone of the sound, and control the function of a cassette tape player or compact disc player. Additional controls may allow for distributing the signal among speakers and for programming the unit for pre-set stations. If the radio has both AM and FM bands, the control unit will also allow for switching between them. An integrated clock circuit may also be tied to the display. Some vehicles also offer remote controls. Remote controls may be located on the steering wheel, armrest, console, or other place convenient for the driver or for passengers, such as the rear seats of a van.

e. **Harness lead**—carries power to the amplifier

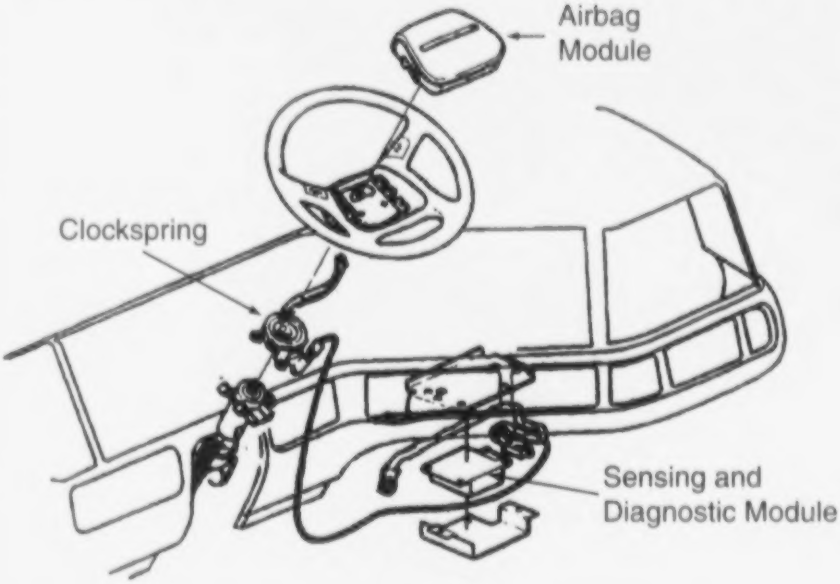
f. **Speakers**—convert the electrical output of the radio (and other audio devices) into sound using an electromagnet which shifts position in response to the varying electrical current to set up vibrations in a flexible membrane

Note: The vibrations reproduce sound. Speakers are also designed to provide specific ranges of sounds, such as higher or lower frequencies.

Objective 11

Parts of an airbag system

Figure 9



Objective 12

Parts of an airbag system and descriptions of their functions

Warning: Always consult the service manual and/or follow manufacturer's procedures prior to troubleshooting or repairing airbag components.

Note: Most new vehicles have front-collision airbags. The driver's airbag module is in the steering wheel. Often, a passenger-side airbag is in the dash. Some vehicles also have side-impact airbags installed in the doors.

a. **Airbag (inflator) module**—an assembly containing an inflatable bag, an inflator and an initiator which act to cushion passengers in a collision

Note: When the **sensing and diagnostic module** (airbag control module) detects a collision, it causes current to flow through the initiator and ignite a chemical (the inflator). The chemical reaction produces a gas that fills the airbag. The gas is generally nitrogen or argon, neither of which is toxic or explosive. Holes in the back of the bag allow it to deflate automatically.

b. **Clockspring**—ensures a continuous electrical circuit between the wiring harness and the driver's airbag module

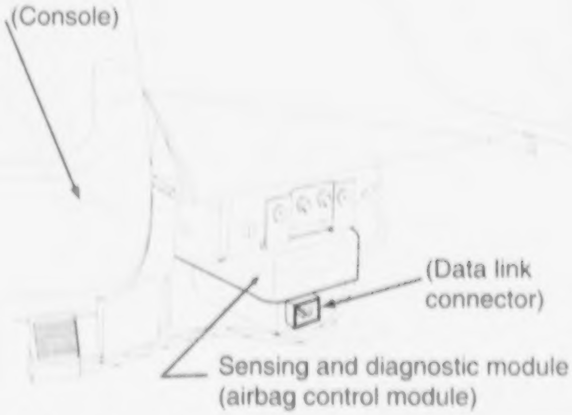
Note: The clockspring winds and unwinds as the steering wheel rotates.

c. **Impact (arming and discriminating) sensors**—threshold-sensitive switches which react to the severity and direction of an impact by sending a signal to the sensing and diagnostic module

Note: Sensors are normally located in the engine compartment and front of the passenger compartment. When a collision of sufficient force (the threshold) and within a specified deployment "window" (such as within 30 degrees on either side of the vehicle's centerline) occurs, the sensor completes an electrical circuit. This signal is processed by the **sensing and diagnostic (airbag control) module**. Systems require that at least two sensors be activated to produce the signal.

d. **Sensing and diagnostic module (airbag control module)**—monitors changes in vehicle velocity (in the form of electrical signals) and causes current to flow to the inflator when impact signals received exceed values stored in memory; also called the diagnostic and energy reserve module

Figure 10



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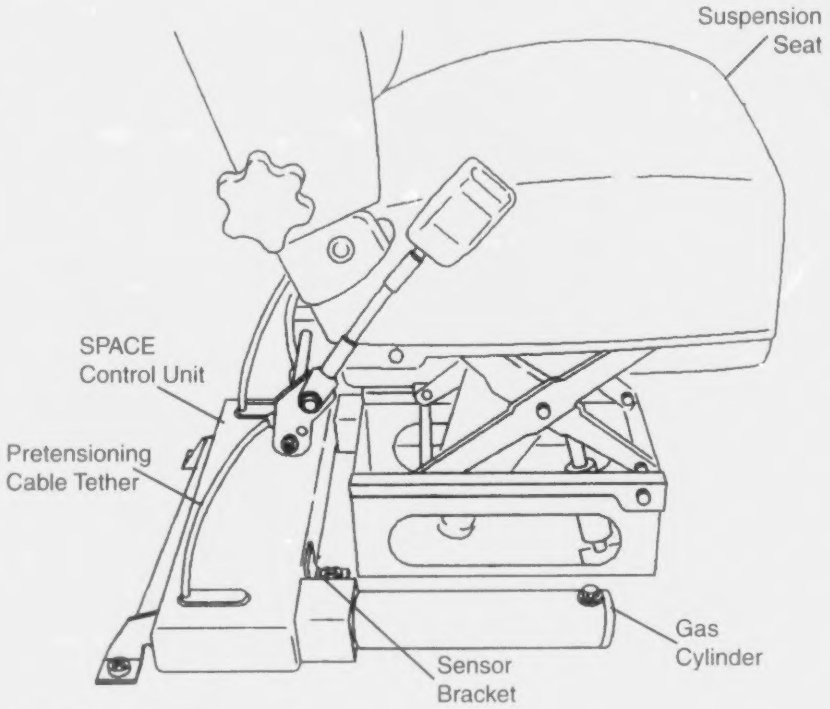
Note: Figure 11 shows a sensing and diagnostic module (SDM) in the center console. The module processes the signals received from the **impact sensors** and compares those signals to a value stored in memory. When the stored (memory) value is exceeded, the module causes current to flow to the inflator to deploy the airbag. (The system may require the module to verify that two processed signals exceed the stored value before allowing current to flow.) The module also performs *diagnostic* functions. It monitors the readiness of the airbag system. If it senses a problem with the system, the module will produce a warning indication. The SDM typically sets a diagnostic trouble code when it detects a malfunction. It also maintains a *reserve power supply* to deploy the airbag when ignition voltage is lost during a crash.

e. **Seat restraint system**—provides additional driver protection in severe frontal collision situations by using gas-cylinder mechanisms mounted at the base of the driver's seat that tighten the seat belts and then lower the seat suspension, moving the seat occupant downward and away from the steering wheel and roof.

Figure 11


Suspension Seat
SPACE Control Unit
Pretensioning Cable Tether
Gas Cylinder
Sensor Bracket

Courtesy of Freightliner LLC

Objective 13

Steps to take to prevent the accidental deployment of an airbag

Warning: Airbags inflate with significant force. Therefore, you must use care when servicing airbag systems and working around them. Dangers exist with various stages of installation. For example, service of deployed airbag systems requires certain precautions. Handling live airbag modules and servicing installed systems involve specific hazards and preventive measures described below.

a. Follow the manufacturer's procedures for handling, servicing and testing airbag systems and related circuits.

b. Wear safety glasses when servicing an airbag system or handling airbag modules.

c. De-energize the system before servicing live airbag modules. You may also have to de-energize the system when servicing other systems, such as those housed in the steering wheel or steering column.

- Disconnect the battery, then wait at least 10 minutes before servicing the airbag system.

  Note: Airbag systems include a diagnostic and energy reserve module that allows deployment of the airbag even after the loss of battery power. The reserve time varies with different systems. Check the service manual for exact time specifications.

- Do not use powered test equipment or test lights to probe airbag circuits except as specifically described by the service procedures.

d. Be careful not to drop, strike or jar sensor modules connected to live airbag systems.

e. Carry live airbag modules with the bag opening (trim cover on driver's airbag module, plastic cover on passenger's module) pointing away from your body.

f. Do not carry airbag modules by the wires or connectors.

g. When (1) placing an airbag module on a bench or other surface, or (2) handling an airbag module attached to a steering column, make sure that the airbag module always faces away from the surface:

- Place an uninstalled live airbag module with its trim or plastic cover facing upward from the bench or other surface and away from loose objects.

- Place a live airbag module attached to a steering column so the airbag module does not face the floor.

  Note: This will reduce the amount of movement by the component (and the potential for injury) in the case of accidental deployment.

h. Follow the disarming procedure exactly. Some systems remain armed for a period of time after power is removed.

Student Supplement 1—Power Windows

Window Lift Motors

Two types of motors are used to raise and lower power windows. The motor may be a permanent-magnet (PM) design or a two-field coil design. A PM motor is insulated, with grounding provided through the master switch. For this reason, PM motors are sometimes referred to as nongrounded motors. The motor has brushes at each end of the armature with connections to both the positive and ground circuits. The direction of rotation depends on the direction of current flow through the brushes.

Two-field coil motors contain two magnetic coils set in opposite directions so that rotation of the armature depends on which coil is energized. These motors are grounded through their housings to the vehicle chassis and are sometimes referred to as grounded motors.

In both designs, armature rotation in one direction raises the window and rotation in the other direction lowers the window. Generally, there is one motor per window.

Switches

Power window operating switches are generally three-position toggle or rocker switches spring-loaded to the OFF position. One ON position lowers the window and the other raises the window. Each operating window has a control switch at the individual window.

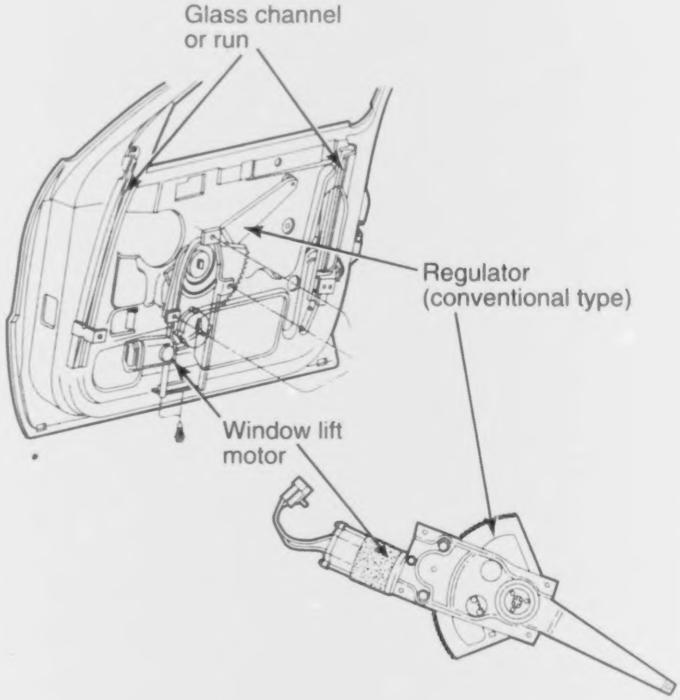
The driver's position has a master control panel that allows control of each of the windows. The control panel is usually located on the driver's door or in a console located between the front seats. The driver's control panel is often equipped with a switch that can be used to disable the individual switches for the other windows. This is a safety feature to prevent the windows from being operated by children.

Regulators

Regulators come in a variety of designs but each has three primary features. First, the regulator must interface directly with the motor output to receive mechanical force from the motor. This feature is generally a gear or a flexible belt with teeth. Second, it must connect directly to the window glass or frame for the glass. This feature is usually a rigid frame or rod to which the window glass is bolted or riveted. Third, the motor interface and window attachment sections must be joined.

The regulator in Figure 1 has a gear on the end of the motor shaft which meshes with a sector gear that swivels on a shaft. The rotation of the sector shaft collapses or extends a lift arm to move the window up and down. The shaft also has a spiral spring that is tightened as the window is lowered. When the window is raised, the uncoiling of the spring reduces the amount of energy that the motor must supply to move the window up. The sector gear provides the interface with the motor, while the collapsible arm joins the sector gear to the window attachment.

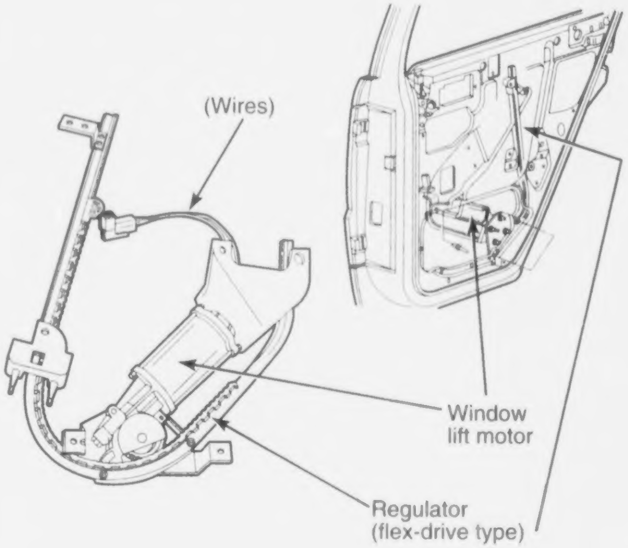
Figure 1


Glass channel or run
Regulator (conventional type)
Window lift motor

Used with permission of Chrysler Corp.

The regulator in Figure 2 uses a *flexible rack* attached to the window. The motor shaft is geared to drive a pinion gear that meshes with the rack. As the pinion gear rotates, the rack is moved forward or backward to raise or lower the window. The upper end of the rack is attached to the window glass, while the toothed portion of the rack provides the interface to the motor.

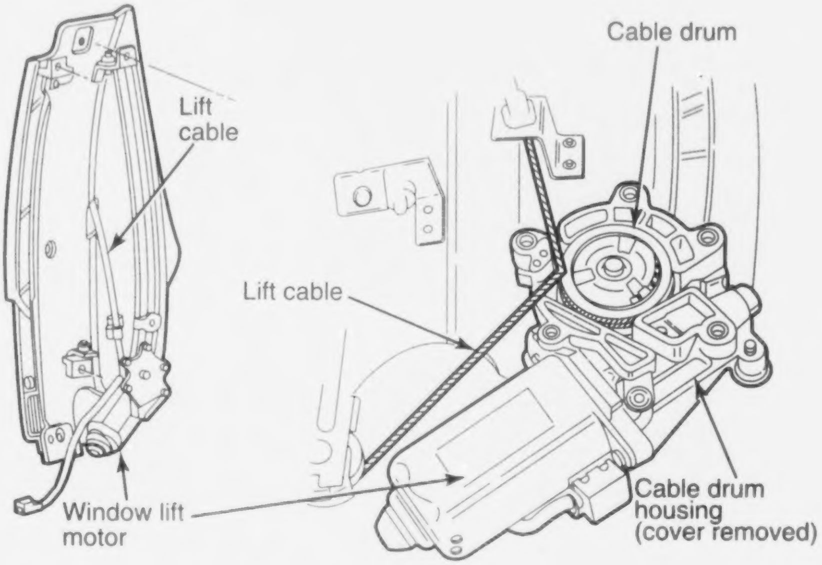
Figure 2


(Wires)
Window lift motor
Regulator (flex-drive type)

Used with permission of DaimlerChrysler Corp.

The regulator in Figure 3 uses a *lift cable*. You may find this type of regulator in a power quarter window.

Figure 3


Lift cable
Cable drum
Lift cable
Window lift motor
Cable drum housing (cover removed)

Used with permission of DaimlerChrysler Corp.

Objective 14

Assignment Sheet 1—Diagnose the Cause of Power Window Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 1	______

Basic Skills

Reading

Critical Thinking

Introduction

Common Problems

Power window circuits use bi-directional motors to raise and lower the windows by reversing current through the motor. Some vehicles offer an express down or one-touch down feature that allows the driver's window to be completely lowered by a quick touch to the switch instead of having to hold the button down. Some four-door vehicles may offer a lockout switch. When activated, this switch prohibits the use of all window switches, except the driver's switch.

The most common problems with power windows include:

- Failure to move (either up or down)
- Failure to go fully up or fully down
- Slow operation
- Intermittent or "sticky" movement
- Misalignment

A power window may malfunction as a result of its electrical circuit or its mechanical regulators (linkages). Each of the problems listed above may be the result of an electrical or a mechanical problem, except for misalignment. Misalignment is nearly always the result of a mechanical problem.

Assignment Sheet 1

Common Electrical Problems

If a power window has an electrical problem, usually the window will not work at all. Problems may occur in the following components:

- Circuit breakers
- Electronic modules and controllers
- Motors
- Switches
- Wiring in the door pillar

If an electrical problem exists, it is usually located in the component that is used the most.

Common Mechanical Problems

- **The window can become misaligned**. The linkages that align the window can become loose, stretched, or otherwise out of alignment. This can cause the window to jump out of its guide track or be difficult to move up or down. In such cases, most windows have adjustment brackets. You can adjust and tighten these brackets manually to realign the window.

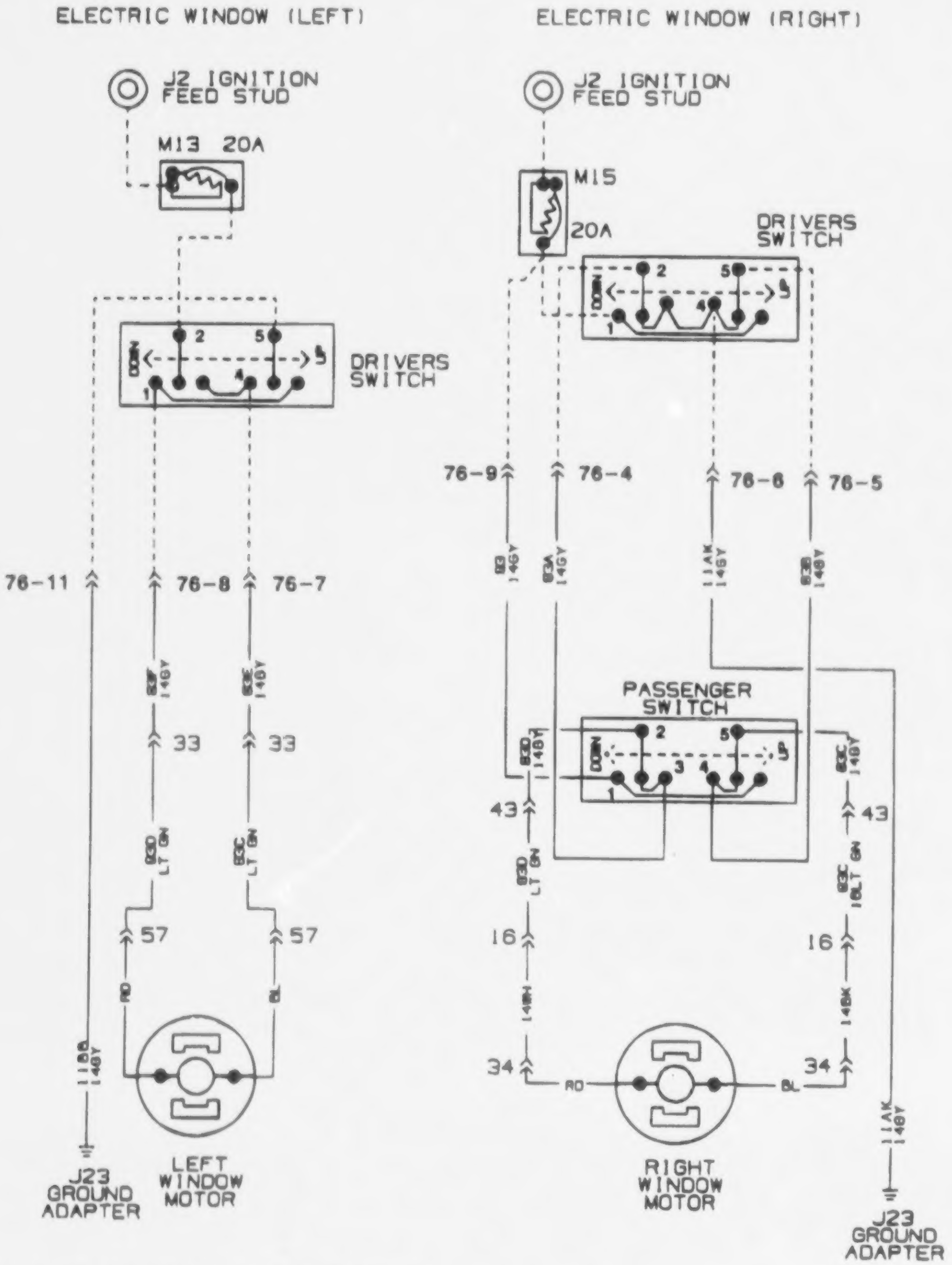
- **The window mounting regulator and brackets can wear and stop functioning properly**. Some windows have small, plastic clips that guide the window in its track. Over time, these clips can wear and/or break, causing the window to bind or fall out of its track. The window regulator, which connects the window to the doorframe, can also wear or bind. This causes the window to become loose, bind or have a sticky operation when the window is moving up or down. These parts are not adjustable and you must replace them.

- **The window frame can interfere with smooth operation**. This can happen when weather strip seals fall out of place, when objects become stuck in the frame, or when a window frame becomes warped due to an accident. Inspecting the window frame can ensure that the window has a smooth, straight area in which to operate.

Directions

Review and use the information found in Objectives 1 and 2, Student Supplement 1, *Power Windows*, and the wiring diagram to answer the following questions. Write your answers in the blank provided.

Figure 1


ELECTRIC WINDOW (LEFT)
ELECTRIC WINDOW (RIGHT)
J2 IGNITION FEED STUD
J2 IGNITION FEED STUD
M13 20A
M15
20A
DRIVERS SWITCH
DRIVERS SWITCH
PASSENGER SWITCH
76-11
76-8
76-7
76-9
76-4
76-6
76-5
33
33
43
43
57
57
16
16
34
34
RD
BL
RD
BL
LT GN
14GY
LEFT WINDOW MOTOR
RIGHT WINDOW MOTOR
J23 GROUND ADAPTER
J23 GROUND ADAPTER

Courtesy of International Truck and Engine Corporation

1300

Assignment Sheet 1

____ 1. The passenger-side power window will only move on command from the passenger-side switch. Technician A says the problem could be the master switch power feed. Technician B says it could be that the passenger side master switch wiring has an open. Who is correct?

- a. Technician A
- b. Technician B
- c. both Technician A and B
- d. neither Technician A nor B

____ 2. The left- and right-side windows in a heavy-duty truck won't move on command with either the driver or passenger side switches. Technician A says the circuit breaker is bad and must be replaced. Technician B says a bad ground circuit could be the cause. Who is correct?

- a. Technician A
- b. Technician B
- c. both Technician A and B
- d. neither Technician A nor B

____ 3. A customer states that the driver-side window is inoperative. Technician A wants to replace the driver-side window switch. Technician B says that you should test the motor for that window before replacing the switch. Who is correct?

- a. Technician A
- b. Technician B
- c. both Technician A and B
- d. neither Technician A nor B

____ 4. A customer states that both the driver- and passenger-side windows are inoperative. Technician A tests the circuit breaker and finds that there is no voltage to the switch side of the circuit breaker, and states that the circuit breaker must be replaced. Technician B says that before you replace the circuit breaker, you should test for voltage at the battery or power side to make sure there is voltage to the switch. Who is correct?

- a. Technician A
- b. Technician B
- c. both Technician A and B
- d. neither Technician A nor B

____ 5. A customer states that both windows operate slowly from both the driver- and passenger-side switches. Technician A says that corrosion on the J23 ground adapter could be the problem. Technician B says that an open circuit breaker could be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 6. A customer states that the passenger-side window will not close using either the driver or passenger side switches, although it opened just fine. Technician A says that the motor on the passenger side is defective and needs to be replaced. Technician B says a ground wire is broken causing the motor not to operate. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 7. If the driver-side switch is broken, the passenger side window can still be operated using the passenger side switch.

a. True
b. False

____ 8. Either window can be operated with the ignition switch OFF.

a. True
b. False

____ 9. Both windows can be operated simultaneously because the motor circuits are parallel.

a. True
b. False

____ 10. Both window circuits have a common ground.

a. True
b. False

Objective 15

Assignment Sheet 2—Diagnose the Cause of Heated, Lighted, and Electrically Operated Mirror Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 4 of the 5 questions correctly per Answers to Assignment Sheet 2	______

Basic Skills

Reading

Critical Thinking

Introduction

Operation

Power mirrors are controlled by motors which move the glass vertically and horizontally. The motors are operated by switches located in the door trim panels or in a center console. Switches may be a rocker, toggle, or paddle type. Some power mirrors are also heated and/or lighted.

Some components can be repaired, such as the wiring. Other components must be replaced. For example, on newer vehicles, the motors are part of the mirror assembly. These motors cannot be replaced separately from the assembly. Similarly, you may have to replace the power mirror switch if you do not obtain satisfactory results from a continuity test. You may also have to replace the mirror glass itself.

Common Mechanical Problems

Common mechanical problems include:

- faulty drive mechanism
- defective mirror glass

Common Electrical Problems

Common electrical problems include:

- faulty fuse
- open or short in the wiring

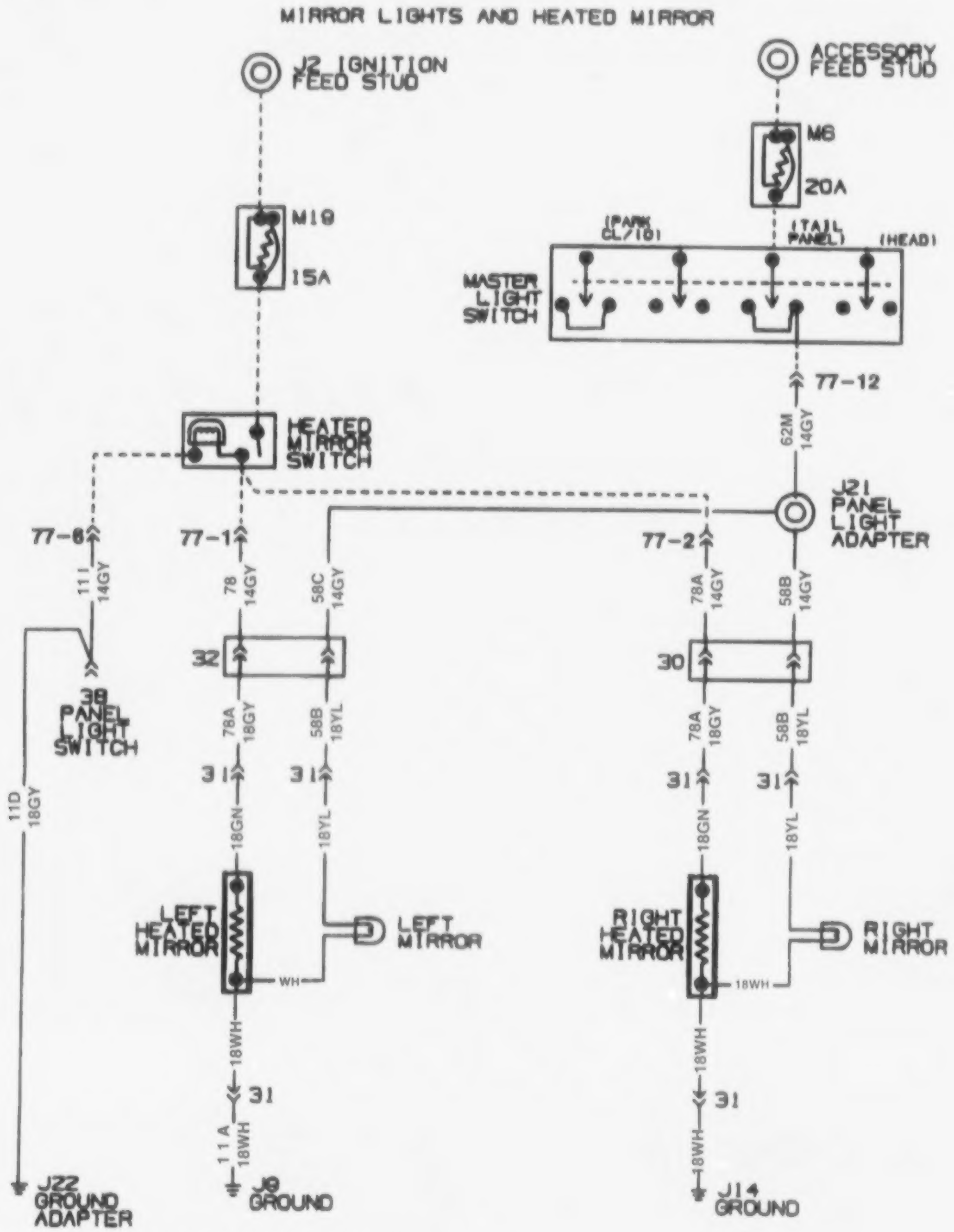
- no continuity between switch terminals
- no voltage at heated mirror switch
- no voltage at headlight switch
- faulty ground connection

Directions

Review and use the information found in Objective 3 and the wiring diagram to answer the following questions. Write your answers in the blank provided.

1304

Figure 1


MIRROR LIGHTS AND HEATED MIRROR
J2 IGNITION FEED STUD
ACCESSORY FEED STUD
M19
15A
M6
20A
(PARK CL/ID)
(TAIL PANEL)
(HEAD)
MASTER LIGHT SWITCH
77-12
62M 14GY
HEATED MIRROR SWITCH
J21 PANEL LIGHT ADAPTER
77-6
77-1
77-2
11 14GY
78 14GY
58C 14GY
78A 14GY
58B 14GY
32
30
38 PANEL LIGHT SWITCH
78A 18GY
58B 18YL
31
11D 18GY
18GN
18YL
LEFT HEATED MIRROR
LEFT MIRROR
RIGHT HEATED MIRROR
RIGHT MIRROR
WH
18WH
11A 18WH
J22 GROUND ADAPTER
J9 GROUND
J14 GROUND

Courtesy of International Truck and Engine Corporation

Assignment Sheet 2

____ 1. A customer says that both electrically powered mirrors are inoperative. Technician A says to check the fuse or circuit breaker first. Technician B says that the first step is to do a system check. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. A customer says that the left mirror has lost its heating capabilities. Technician A says that an open in the 18GN circuit is the problem. Technician B says that an open ground circuit (J9) could be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. Both mirrors have inoperative lights. Technician A says that the M19, 15-amp circuit breaker could be bad. Technician B says that the M6, 20-amp circuit breaker could be bad. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. The heating feature on both the right and left mirrors is in operative. Technician A says that the 20-amp, M6 circuit breaker could be bad. Technician B says there could be an open ground at J9. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. A customer says that the light in the driver-side mirror is inoperative. Technician A says that the master light switch could be the problem. Technician B says that the heated mirror switch could be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 16

Assignment Sheet 3—Diagnose the Cause of Electric Door Lock Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	______
• Answered a minimum of 4 of the 5 questions correctly per Answers to Assignment Sheet 3	______

Basic Skills

Reading

Critical Thinking

Introduction

Common Problems

Door locks are two-position devices with the door locked in one position and unlocked in the other. To shift between the positions, power door locks use either a solenoid or an electric motor. Through use, both solenoids and electric motors can weaken to the point that they can no longer develop the force required to shift the locking mechanism between positions. Similarly, the wiring between the body and the door can wear after repeated opening and closing of the door.

One of the complications of diagnosing electric door lock problems is the number of switches involved. Most systems have a switch for each door. Often, one or both front door panels have switches that operate all of the door locks.

Electric (power) door locks have manual backup systems as a safety precaution. Both the power and mechanical door locks use many of the same mechanical parts, such as latching mechanisms. As a result, a door lock malfunction, even in a vehicle equipped with power locks, may have electrical or mechanical causes. The most common problems for a power door lock circuit include:

- power door locks are inoperative from all door lock switches
- power door locks are inoperative from one door lock switch only
- all power door locks will actuate in one position (lock or unlock) from all switches
- all power door locks will actuate in one position (lock or unlock) from one door lock switch

- One or more door lock actuators are inoperative from all switches

Common Electrical Problems

Common electrical problems include:

- faulty actuators (solenoids or motors)
- faulty switches
- faulty door lock relay
- fuses
- worn wiring

Common Mechanical Problems

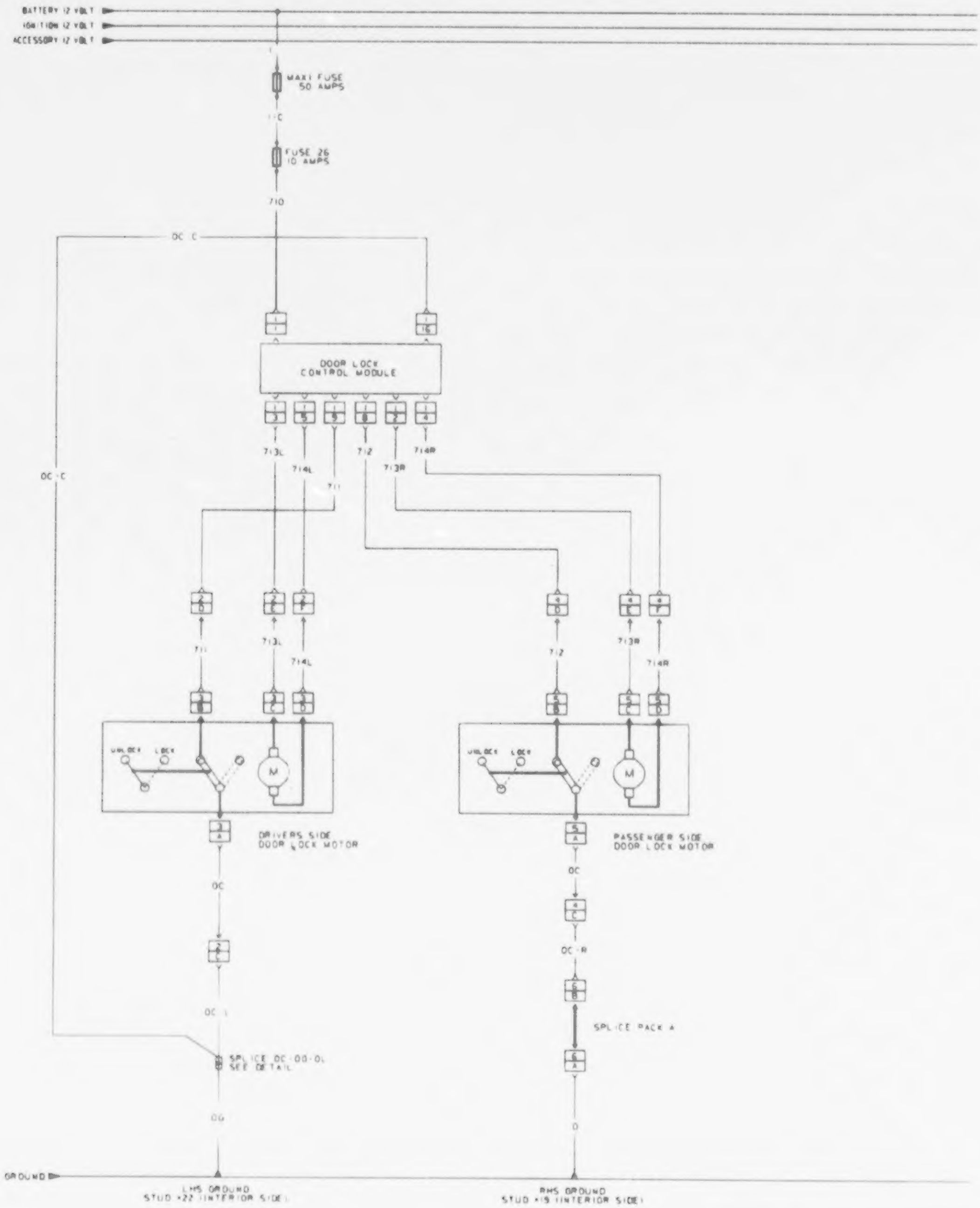
The most common mechanical problems include:

- worn and/or binding door latches
- binding, worn or loose linkages/connecting rods
- frozen or stuck lock cylinders

Directions

Review and use the information found in Objectives 4 and 5 and the wiring diagram to answer the following questions. Write your answer in the blank provided.

Figure 1


BATTERY 12 VOLT
IGNITION 12 VOLT
ACCESSORY 12 VOLT
MAXI FUSE 50 AMPS
FUSE 26 10 AMPS
710
OC C
OC C
DOOR LOCK CONTROL MODULE
1 1
1 16
713L
714L
711
712
713R
714R
UNLOCK
LOCK
M
DRIVERS SIDE DOOR LOCK MOTOR
PASSENGER SIDE DOOR LOCK MOTOR
OC
OC R
SPLICE PACK A
SPLICE OC-OG-OL SEE DETAIL
OG
O
GROUND
LHS GROUND STUD #22 (INTERIOR SIDE)
RHS GROUND STUD #15 (INTERIOR SIDE)

Assignment Sheet 3

____ 1. All door locks are inoperative . Technician A says an open circuit at Fuse 26, 10-amp could be the cause. Technician B says a short to ground at circuit 710 could be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. The left front door will not unlock. Technician A says an open at circuit 713L could be the cause. Technician B says a defective left lock motor is the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. All door locks are inoperative. Technician A says the right lock motor is the cause. Technician B says that circuit LHS ground is open and causing the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. The power door locks will unlock both doors but will not lock both doors. Technician A says the door lock relay could be the cause. Technician B says the drivers side door lock switch is the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. The right door lock switch will not operate the door locks. Technician A says to try the left front switch to see if the locks operate and if they do, pull the right front switch and check it. Technician B says to check the power to the right front switch. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

13.0

Objective 17

Assignment Sheet 4—Diagnose the Cause of Radio Reception Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	____
• Answered a minimum of 8 of the 10 questions correctly per Answers to Assignment Sheet 6	____

Basic Skills

Reading

Critical Thinking

Introduction

Problem Sources

Radio reception problems may have internal causes, such as malfunctions in the antenna, the antenna lead, or the tuner. They may also result from external factors. For example, FM stations have a more limited broadcast range. As a vehicle nears the limits of this range, the signal weakens, which can result in static and flutter (the signal fading in and out). AM stations may be blocked in tunnels or other obstructions that block signals from above. Signals may be disrupted by other strong electromagnetic sources, such as nearby radio stations, power lines, and neon lights. Interference may also be produced by other systems in the vehicle. The charging system also produces interference from motors—such as the windshield wiper motor—and from sparking at the brushes.

Noise can enter the radio circuit in two ways:

- *Radiated noise* is received by the antenna along with radio signals and carried to the radio, where they are amplified and output to the speakers. Radiated noise may originate outside of the vehicle, such as nearby power lines, or within the vehicle, such as electric motors or fuel pumps. Radiated noise is particularly noticeable on weak stations at normal volume.
- *Conducted noise* originates in the radio power feed circuits by way of the alternator, power module, or hot-wired circuits such as some light systems. The easiest way to distinguish between radiated and conducted noise is to disconnect the antenna lead and operate the radio at low volume. If the noise disappears when the antenna is disconnected, then the noise is radiated.

Assignment Sheet 4

Service manuals provide directions for isolating noise. Typical questions useful in diagnosing problems with noise include the following:

- Is there noise on AM, FM, or both?
- Is there noise on other audio devices, such as cassette and CD players?
- Is there noise with the ignition switch in the accessory and run positions without the engine running?
- Is there noise with the engine running or when it is not running?
- Does the noise change when the volume control is adjusted?
- Does the noise change when the engine speed changes?
- Is there noise only when certain electrical equipment is operated?
- Is there noise any time the radio is on or only during certain situations, such as driving over bumps?

In addition to static, other problems can develop in vehicle audio systems. These may include the following:

- The entire system may be inoperative.
- The unit may provide power indications (displays, indicators, etc.) but no sound.
- A speaker may not work or the speakers on one side or in the front or rear may not work.
- A component of the system, such as the radio or cassette player, may not work while the rest of the system functions.
- A function of the system may not work, such as an inoperative cassette rewind, CD ejection, radio station selection, volume control, AM or FM band, memory functions, treble or bass control, clock, etc.
- The sound quality may be poor.
- A function may perform poorly, such as a cassette playing slowly, a CD skipping, or the clock gaining time.
- The problem may occur all the time or intermittently.

Assignment Sheet 4

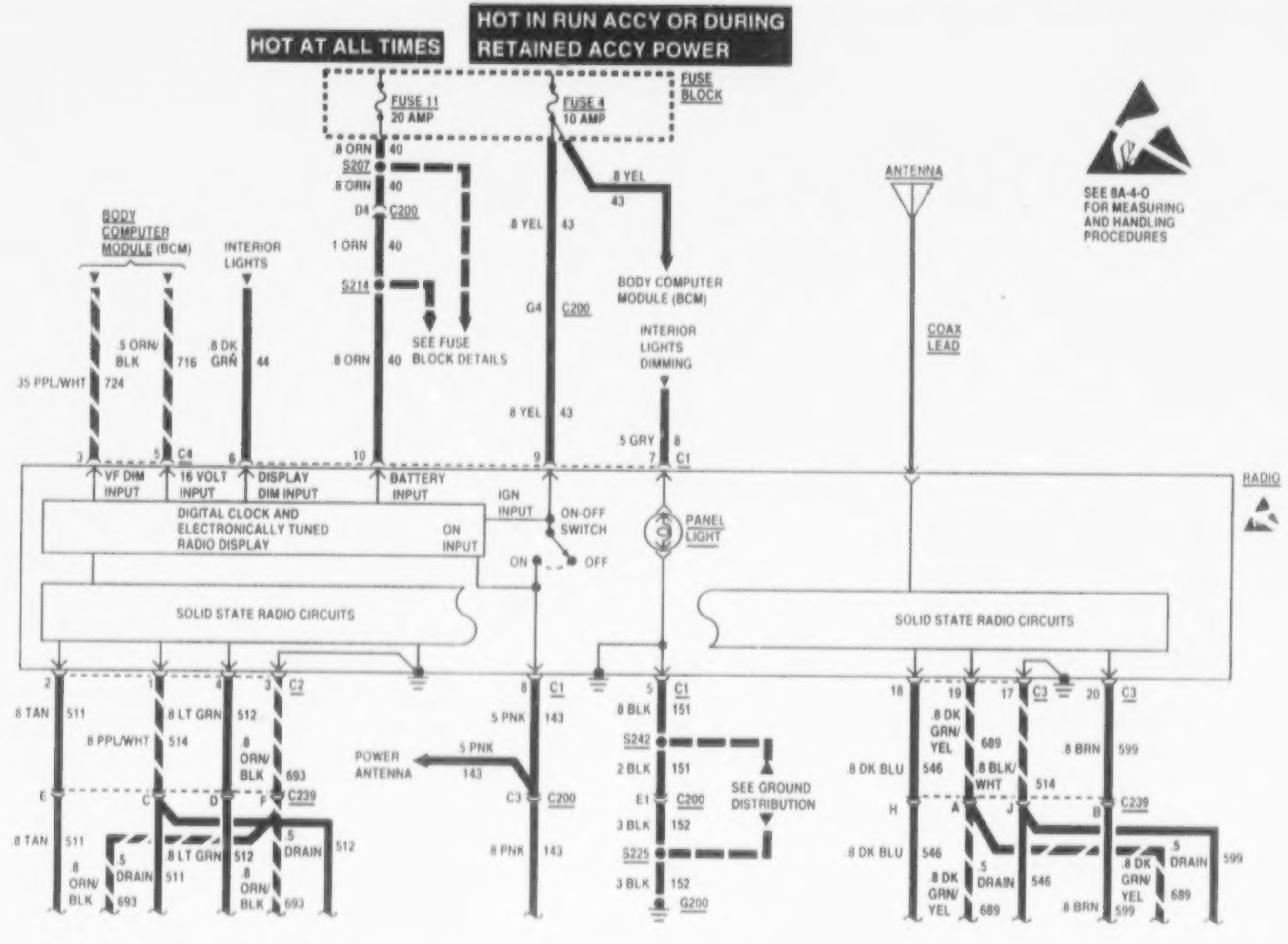
Sound Systems

Many audio components are electrically sensitive. For example, because most speakers use magnetic coils, they have a designed electrical polarity. They have specific positive and negative terminals which must be correctly wired. Speakers are also designed to have a specific resistance in the internal coil. This characteristic is called impedance. The impedance of speakers must be matched to the system and to that of other speakers for good sound quality and to avoid damaging system components. While most electrical equipment is grounded to the vehicle chassis, some audio systems have what is called a floating ground. A second wire completes the speaker circuit. Another concern with audio circuits is that they should not be operated without a load (such as operating a sound system without speakers installed). Many audio systems boost the circuit power in order to drive the speakers. If the current is not reduced through the normal load represented by the speakers, other equipment may be damaged.

Directions

Study the troubleshooting charts and circuit diagrams on the following pages and answer the questions that accompany each one. Write the correct letter in the blank provided.

Assignment Sheet 4


HOT AT ALL TIMES
HOT IN RUN ACCY OR DURING RETAINED ACCY POWER
FUSE BLOCK
FUSE 11 20 AMP
FUSE 4 10 AMP
.8 ORN 40
S207
.8 ORN 40
D4 C200
1 ORN 40
S214
SEE FUSE BLOCK DETAILS
.8 ORN 40
.8 YEL 43
.8 YEL 43
G4 C200
.8 YEL 43
BODY COMPUTER MODULE (BCM)
INTERIOR LIGHTS DIMMING
.5 GRY 8
ANTENNA
COAX LEAD
SEE 8A-4-0 FOR MEASURING AND HANDLING PROCEDURES
BODY COMPUTER MODULE (BCM)
INTERIOR LIGHTS
.35 PPL/WHT 724
.5 ORN/BLK 716
.8 DK GRN 44
3 5 C4 6 10 9 7 C1
VF DIM INPUT
16 VOLT INPUT
DISPLAY DIM INPUT
BATTERY INPUT
IGN INPUT
ON-OFF SWITCH
ON OFF
ON INPUT
PANEL LIGHT
RADIO
DIGITAL CLOCK AND ELECTRONICALLY TUNED RADIO DISPLAY
SOLID STATE RADIO CIRCUITS
SOLID STATE RADIO CIRCUITS
2 1 4 3 C2
.8 TAN 511
.8 LT GRN 512
.8 PPL/WHT 514
.8 ORN/BLK 693
E C D F C239
.8 TAN 511
.5 DRAIN 511
.8 LT GRN 512
.5 DRAIN 512
.8 ORN/BLK 693
.8 ORN/BLK 693
8 C1
.5 PNK 143
POWER ANTENNA
.5 PNK 143
C3 C200
.8 PNK 143
5 C1
.8 BLK 151
S242
2 BLK 151
E1 C200
SEE GROUND DISTRIBUTION
3 BLK 152
S225
3 BLK 152
G200
18 19 17 C3 20 C3
.8 DK GRN/YEL 689
.8 BLK/WHT 514
.8 DK BLU 546
.8 BRN 599
H A J B C239
.8 DK BLU 546
.8 DK GRN/YEL 689
.5 DRAIN 546
.8 DK GRN/YEL 689
.5 DRAIN 599
.8 BRN 599

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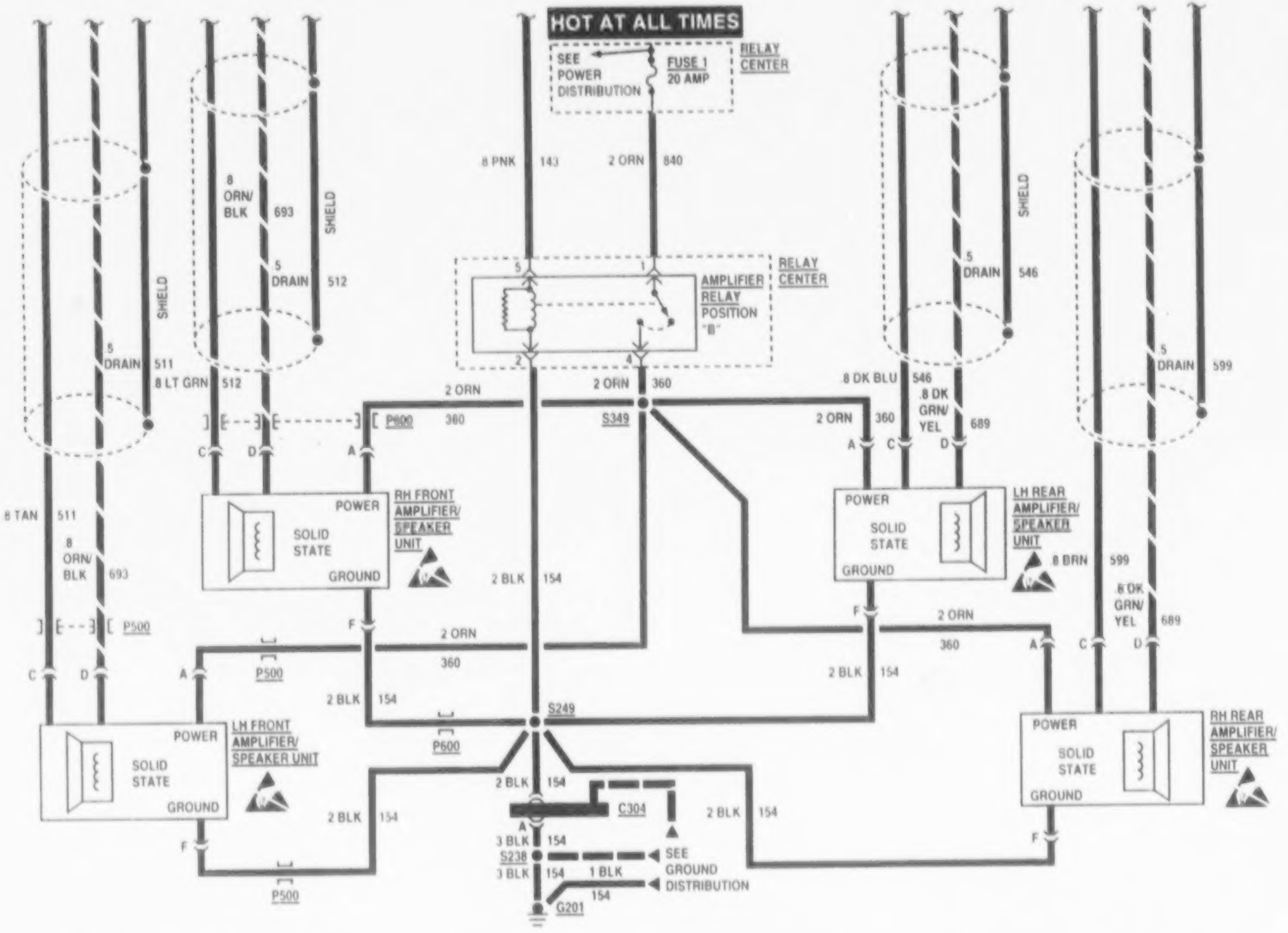
HOT AT ALL TIMES
SEE POWER DISTRIBUTION
FUSE 1 20 AMP
RELAY CENTER
8 PNK 143
2 ORN 840
AMPLIFIER RELAY POSITION "B"
RELAY CENTER
5
1
2
4
2 ORN
2 ORN 360
360
S349
P600
2 ORN 360
8 ORN/ BLK 693
SHIELD
5 DRAIN 512
8 LT GRN 512
5 DRAIN 511
SHIELD
8 TAN 511
8 ORN/ BLK 693
P500
C
D
A
F
RH FRONT AMPLIFIER/ SPEAKER UNIT
POWER
SOLID STATE
GROUND
LH FRONT AMPLIFIER/ SPEAKER UNIT
2 BLK 154
2 ORN
360
P500
S249
P600
SHIELD
5 DRAIN 546
8 DK BLU 546
.8 DK GRN/ YEL 689
5 DRAIN 599
LH REAR AMPLIFIER/ SPEAKER UNIT
8 BRN 599
.8 DK GRN/ YEL 689
2 ORN
360
2 BLK 154
RH REAR AMPLIFIER/ SPEAKER UNIT
C304
3 BLK 154
S238
1 BLK
154
SEE GROUND DISTRIBUTION
G201

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Trouble Shooting Hints

- Try the following checks before doing the System Check.

1. Check Fuse 4.
2. Check Fuse 11 by operating the Front Cigar Lighter.
3. Check fuse 1 in Relay Center (Delco-Bose® Music System).
4. Check that the Antenna connector and coaxial cable are properly connected.
5. For proper noise diagnosis, take the vehicle outside where signals are strong. Close the hood, and keep away from metal buildings or sources of radio interference.
6. Coated screws or bolts can cause a poor ground condition. Scrape ground screw clean of any paint or varnish.
7. If Radio does not operate during Retained Accessory Power, or if there is no power to Fuse 4, refer to Section 8A-15 for diagnosis
8. Before troubleshooting a suspect speaker, check all connections to that speaker.

- Go to System Check for a guide to normal operation.
- Go to System Diagnosis for diagnostic tests.

System Check

- Use the System Check Table as a guide to normal operation.
- Refer to System Diagnosis for a list of symptoms and diagnostic setups.

SYSTEM CHECK TABLE

ACTION	NORMAL RESULTS
With the Ignition Switch in RUN, turn the Radio ON	The Digital display comes on The Digital Clock operates Sound comes from all four Speakers
Operate the Radio controls	Consult the vehicle owner's manual for information regarding the operation of the controls
Turn Light Switch to PARK	The Panel Light comes on The Digital display dims

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System Diagnosis

- Do the tests listed for your symptom in the Symptom Table below.
- Tests follow the Symptom Table.

SYMPTOM TABLE

SYMPTOM	DO TEST
Radio does not appear to work (no display, no sound)	A: Ignition Power Test B: Battery Power Test
Panel light does not come on	C: Panel Light test
No Vacuum fluorescent display, but the Radio plays	D: Display test
Vacuum fluorescent display does not dim	E: Display Dimming test
Without Delco-Bose® Music System only, no sound or distorted sound comes from a Speaker	F: Speaker Test
With Delco-Bose® Music System only, Radio appears to work (display lights) but no sound comes from and Speaker	G: Amplifier Relay Test
With Delco-Bose® Music System only, no sound or distorted sound comes from a Speaker Unit	H: Amplifier/Speaker Unit Test
Excessive noise comes from all Speakers	I: Noise Diagnosis

A: IGNITION POWER TEST

Measure: VOLTAGE
At: RADIO CONNECTOR C1 (Disconnected)
Condition:

- Ignition Switch: RUN

Measure Between	Correct Voltage	For Diagnosis
9 (YEL) & Ground	Battery	See 1
9 (YEL) & 5 (BLK)	Battery	See 2

- If both voltages are correct, go the Test B.

1. Check YEL (43) wire for an open.
2. Check BLK (151) and (152) wires for an open to ground.

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Assignment Sheet 4

B: BATTERY POWER TEST

Measure: VOLTAGE
At: RADIO CONNECTOR C1 (Disconnected)

Measure Between	Correct Voltage	For Diagnosis
10 (ORN) & Ground	Battery	See 1

- If the voltage is correct, remove Radio for service.

1. Check ORN (40) wire for an open.

C: PANEL LIGHT TEST

Measure: VOLTAGE
At: RADIO CONNECTOR C1 (Disconnected)
Conditions:

- Ignition Switch: RUN
- Light Switch: PARK
- Instrument Panel at maximum brightness

Measure Between	Correct Voltage	For Diagnosis
7 (GRY) & Ground	Battery	See 1

- If the voltage is correct, remove Radio for service.

1. Check GRY (8) wire for an open (see Section 8A-117).

D: DISPLAY TEST

Measure: VOLTAGE
At: RADIO CONNECTOR C4 (Disconnected)
Condition:

- Ignition Switch: RUN

Measure Between	Correct Voltage	For Diagnosis
5 (ORN/BLK) & Ground	Approx. 16 volts	See 1

- If the voltage is correct, remove Radio for service.

1. Check ORN/BLK (716) wire for an open. Refer to Instrument Panel Dimming, Section 8A-88, for diagnosis.

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E: DISPLAY DIMMING TEST

Measure: VOLTAGE
At: RADIO CONNECTOR C4 (Disconnected)
Conditions:

- Ignition Switch: RUN
- Light Switch: PARK

Measure Between	Correct Voltage	For Diagnosis
3 (PPL/WHT) & Ground	7 to 12 volts	See 1

- If the voltage is correct, remove Radio for service.

1. Check PPL/WHT (724) wire for an open (see Section 8A-88).

F: SPEAKER TEST (TABLE 1)

Connect: 1.5V BATTERY
At: SUSPECT SPEAKER
Condition:

- Speaker Connector: DISCONNECTED
  CAUTION: Do not leave battery connected for more than one second. Prolonged connection could damage speaker.

Action	Correct Result	For Diagnosis
Connect battery across Speaker terminals	Speaker "pops"	See 1

- If the result is correct, check Speaker for a short to ground. If OK, go to Table 2.

1. Replace suspect Speaker.

F: SPEAKER TEST (TABLE 2)

Measure: AC VOLTAGE OUTPUT FOR SUSPECT SPEAKER
At: RADIO
Conditions:

- Ignition Switch: RUN
- Radio: ON (High volume)

Measure Between	Correct Voltage	For Diagnosis
Outputs for suspect Speaker with Radio tuned to a strong signal (See schematic)	Varying around 1 volt AC	See 1

- If the result is correct, check the wires between the Radio and suspect Speaker.

1. Remove Radio for service.

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Assignment Sheet 4

G: AMPLIFIER RELAY TEST (TABLE 1)

Measure: VOLTAGE
At: RELAY CENTER POSITION "B"
Conditions:

- Amplifier Relay: DISCONNECTED
- Ignition Switch: RUN
- Radio: ON

Measure Between	Correct Voltage	For Diagnosis
5 & Ground	Battery	See 1
5 & 2	Battery	See 2
1 & Ground	Battery	See 3

- If all voltages are correct, go to Table 2.

1. Check PNK (143) wire.
2. Check BLK (154) wire.
3. Check ORN (840) wire.

G: AMPLIFIER RELAY TEST (TABLE 2)

Connect: FUSED JUMPER
At: RELAY CENTER POSITION "B"
Conditions:

- Amplifier Relay: DISCONNECTED
- Ignition Switch: RUN
- Radio: ON

Jumper Between	Correct Result	For Diagnosis
1 & 4	Sound comes from Speakers	See 1

- If the result is correct, replace Amplifier Relay.

1. Check ORN (360) wire to S349 for an open.

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H: AMPLIFIER/SPEAKER UNIT TEST (TABLE 1)

Measure: VOLTAGE
At: SUSPECT AMPLIFIER/SPEAKER UNIT CONNECTOR (Disconnected)
Conditions:

- Ignition Switch: RUN
- Radio: ON

Measure Between	Correct Voltage	For Diagnosis
A (ORN) & Ground	Battery	See 1
A (ORN) & F (BLK)	Battery	See 2

- If both voltages are correct, go to Table 2.

1. Check ORN (360) wire.
2. Check BLK (154) wire.

H: AMPLIFIER/SPEAKER UNIT TEST (TABLE 2)

Measure: AC VOLTAGE
At: SUSPECT AMPLIFIER/SPEAKER UNIT CONNECTOR (Disconnected)
Conditions:

- Ignition Switch: RUN
- Radio: ON (Tuned to strong signal)
- Voltmeter: On low AC volts scale

Measure Between	Correct Voltage	For Diagnosis
Terminals C & D (See schematic)	Varying around 1 volt AC	See 1

- If the voltage is correct, go to Table 3.

1. Go to Table 4

H: AMPLIFIER/SPEAKER UNIT TEST (TABLE 3)

Connect: ANALOG OHMMETER
At: SUSPECT SPEAKER
Conditions:

- Ohmmeter set on RX1 scale
- Speaker removed from Amplifier/Speaker Unit enclosure

Connect	Correct Result	For Diagnosis
Analog ohmmeter across Speaker terminals	Speaker "pops"	See 1

- If the result is correct, replace suspect Amplifier/Speaker Unit.

1. Replace suspect Speaker.

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Assignment Sheet 4

H: AMPLIFIER/SPEAKER UNIT TEST (TABLE 4)

Measure: AC VOLTAGE OUTPUT FOR SUSPECT SPEAKER
At: RADIO
Conditions:

- Ignition Switch: RUN
- Radio: ON (Tuned to a strong signal)
- Voltmeter: On low AC volts scale

Measure Between	Correct Voltage	For Diagnosis
Radio output terminals for suspect Speaker (See schematic)	Varying around 1 volt AC	See 1

- If the voltage is correct, check the wires between the Radio and the suspect Speaker.

1. Remove the Radio for service.

Continued on next page.

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Assignment Sheet 4

I: Noise Diagnosis

Unplug the Antenna at the back of the Radio.

- If the noise disappears, it was being picked up by the Antenna. Consult the Delco Sound Service Guide for Antenna noise diagnosis.
- If the noise persists, it is coming in the Radio wiring. Refer to the following chart for a possible cause and corrective action.

NOISE SYMPTOM TABLE

SYMPTOM	POSSIBLE CAUSE	REPAIR ACTION
Harsh popping noise that changes with engine rpm	Injector solenoid	Refer to engine manufacturer's troubleshooting guide
High whine (like a siren) that changes with engine rpm	Generator noise	Add filter package 1224205 to the Power Line and/or memory lead to the Radio. See Fig. 2 page 150-10 By-pass the Generator output with 250 MFD 100v capacitor. See Fig. 3 page 150-10 Install a braided ground strap on the Radio. See Fig. 1 page 150-10 Run a direct wire from Battery (+) to Generator Exchange the defective Radio with a good Radio. If noise disappears, send the defective Radio for repair Replace Generator
Noise occurs only when an accessory is on	Condition in that accessory	Install filter package 1224205 in the power lead(s) to that accessory. See Fig. 2 page 150-10 Install a .5 MFD by-pass capacitor at the power lead to that accessory Consult Delco Sound Service Guide
All stations weak, noisy (both AM and FM)	Defective Antenna or lead-in wire	Temporarily replace the Antenna with another one. Repair/replace the defective one if the Radio reception improves. Check at the Antenna Coax Lead-in and the connector
(AM only) weak, noisy	AM alignment	Remove Radio for repair
(FM only) weak, noisy	FM alignment	Remove Radio for repair
Noise present with engine not running	ECM or Digital Cluster	Consult the Delco Sound Service Guide
Noise that stops when Antenna is unplugged from back of Radio	Antenna noise	Replace defective Antenna with a good Antenna. If noise disappears, repair or replace the defective Antenna. Check Antenna ground, coaxial braid, and grounds at connectors. If noise persists with replacement Antenna, the problem must be repaired at the source of noise (generator, Ignition System, accessory, etc). See Delco Sound Service Guide for noise "sniffing" procedures.

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Radio

For more detailed noise repair procedures consult the Delco Sound Service Guide. Service procedures are given for:

- accessory noise
- CB antennas and noise
- computer noise
- windshield antennas
- shielding of wiring and components
- locating vehicle noise

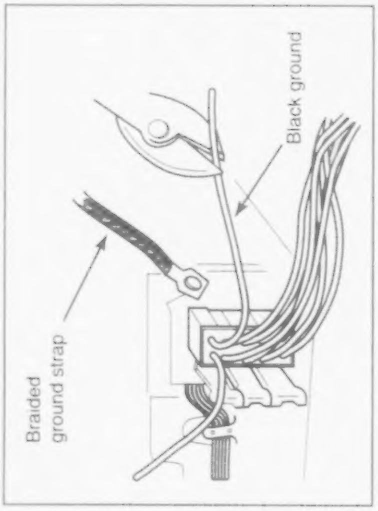
Braided ground strap
Black ground

Figure 1 - Cut the black (ground) wire from the black plug at the back of the Radio and run a braided ground strap from the case of the Radio to good, unpainted body ground.

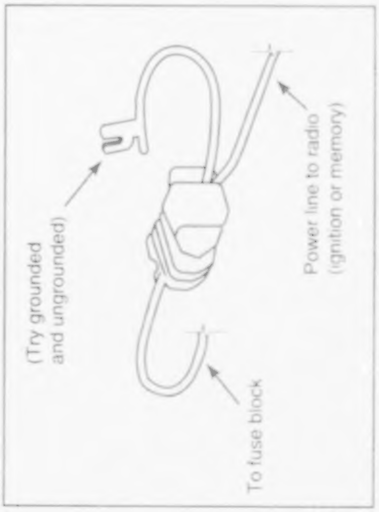
(Try grounded and ungrounded)
To fuse block
Power line to radio (ignition or memory)

Figure 2 - Install a 1224205 filter package.

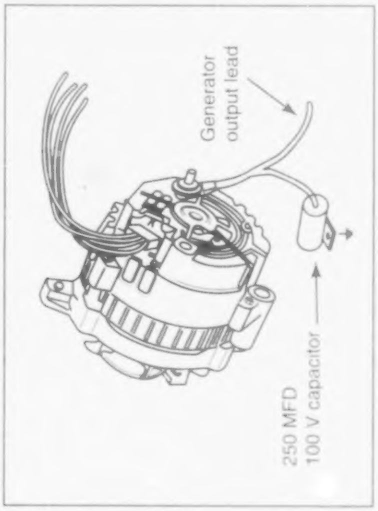
Generator output lead
250 MFD 100 V capacitor

Figure 3 - Install a 250 MFD 100V capacitor on the generator output lead to ground

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Assignment Sheet 4

____ 1. A vehicle comes into the shop with an inoperative radio that has no display. Technician A says that an open fuse #4 may be the cause. Technician B says that a broken coax lead could be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. A vehicle's power antenna fails to extend while the radio is in operation. Technician A says that a defective drive motor can cause the problem. Technician B says an open at circuit 143 could be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. A vehicle's radio will not play, but the display is active. Technician A says an open at circuit P500 could be the cause. Technician B says an open splice at S249 could be the problem. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. When performing a noise diagnosis, Technician A says you should perform the test inside the shop building. Technician B says the hood should be open while performing the test. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. While checking a noisy radio, Technician A says the problem could be a defective ignition system. Technician B says that improperly shielded cables could be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 6. While diagnosing the cause for radio problems, Technician A says that the System Check is a guide to normal operations. Technician B says that you should refer to the System Diagnosis for a list of symptoms and diagnostic setups. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 7. A client complains that the panel light does not come on. Technician A says that an ignition power test should be performed. Technician B says that the display dimming test should be performed. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

_____ 8. When performing a speaker test, which of the following should be connected across the speaker terminals?

a. Ohm meter
b. volt meter
c. 1.5v battery
d. fused jumper

_____ 9. When performing an amplifier relay test, which of the following should be connected across terminals 1 & 4?

a. Ohm meter
b. volt meter
c. 1.5v battery
d. fused jumper

_____ 10. While performing a noise diagnosis test, Technician A says if the antenna is unplugged and the noise disappears, the problem is in the antenna. Technician B says a high whining sound similar to a siren coming from the vehicle may be a noise from the generator. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 18

Assignment Sheet 5—Diagnose the Cause(s) of the Airbag Warning Light Staying On or Flashing

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Directions were followed	_____
• Answered a minimum of 4 of the 5 questions correctly per Answers to Assignment Sheet 7	_____ _____

Basic Skills

Reading Critical Thinking

Introduction

Warning: Always consult the service manual and/or follow manufacturer's procedures prior to troubleshooting or repairing airbag components.

Loose connections are often the cause of failures in airbag systems. Careless service of the system or of nearby components is frequently to blame. Because airbag systems are not routinely operated, most have self-diagnostic systems. The sensing and diagnostic module (SDM), also called the airbag control module, tests the system each time the engine is started. Typically, the system displays a light while the test is being run to indicate the status of the test. For example, on many vehicles, the light flashes seven to nine times and then goes off. A defective airbag system may be indicated if the light pattern is different, including:

- the light does not illuminate at all;
- the light comes on while the vehicle is being driven;
- the light flashes and then remains on;
- the light does not flash but remains on; or
- the light flashes when the engine is cranking.

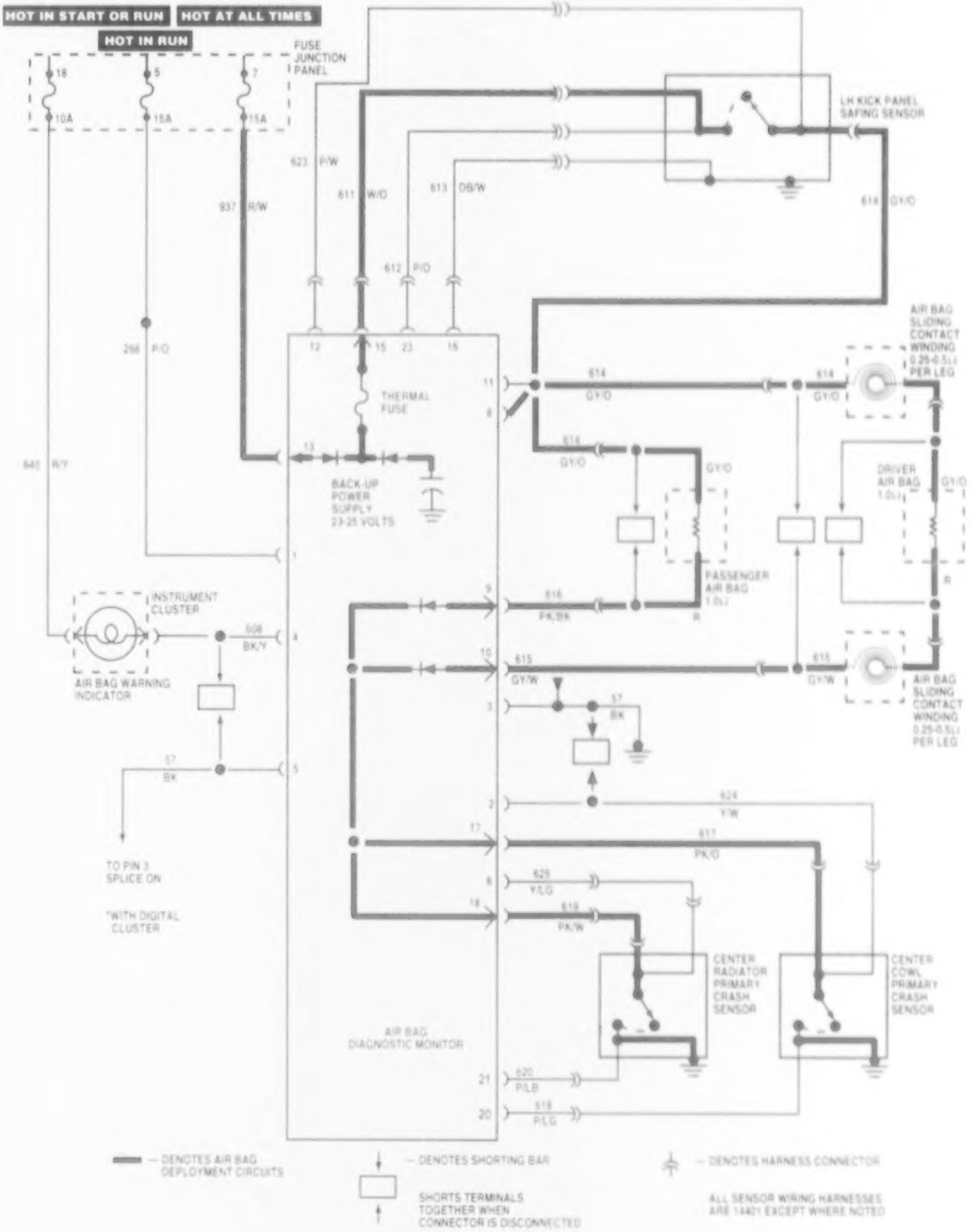
If the driver reports any of these conditions, you should conduct the appropriate tests. The SDM may set a diagnostic trouble code when it detects a malfunction.

This assignment sheet will allow you to practice troubleshooting two failure indications. Troubleshooting charts are provided for a condition in which the light remains on and another in which it flashes while the engine is cranking (during which time the light should be steady).

Assignment Sheet 5

Directions

Study the troubleshooting charts on the following pages and answer the questions that accompany each one. Write the correct letter in the blank provided.


HOT IN START OR RUN
HOT AT ALL TIMES
HOT IN RUN
FUSE JUNCTION PANEL
18
10A
5
15A
7
15A
623 P/W
611 W/O
613 DB/W
937 R/W
612 P/O
298 P/O
640 R/Y
LH KICK PANEL SAFING SENSOR
614 GY/O
12
15
23
16
THERMAL FUSE
13
BACK-UP POWER SUPPLY 23-25 VOLTS
11
8
1
614 GY/O
AIR BAG SLIDING CONTACT WINDING 0.25-0.5Ω PER LEG
GY/O
DRIVER AIR BAG 1.0Ω
PASSENGER AIR BAG 1.0Ω
R
9
616 PK/BK
INSTRUMENT CLUSTER
AIR BAG WARNING INDICATOR
608 BK/Y
4
10
615 GY/W
3
57 BK
5
TO PIN 3 SPLICE ON
*WITH DIGITAL CLUSTER
2
624 Y/W
17
617 PK/O
6
625 Y/LG
18
619 PK/W
CENTER RADIATOR PRIMARY CRASH SENSOR
CENTER COWL PRIMARY CRASH SENSOR
AIR BAG DIAGNOSTIC MONITOR
21
620 P/LB
20
618 P/LG
— DENOTES AIR BAG DEPLOYMENT CIRCUITS
— DENOTES SHORTING BAR
SHORTS TERMINALS TOGETHER WHEN CONNECTOR IS DISCONNECTED
— DENOTES HARNESS CONNECTOR
ALL SENSOR WIRING HARNESSES ARE 14401 EXCEPT WHERE NOTED

Used with permission of Ford Motor Co.

Assignment Sheet 5

Note: The codes listed in the following chart are specific to the Ford Motor Company. Other equipment manufacturers may use different codes. Always check the service manual/manufacturer's procedures for proper code listing.

AIR BAG DIAGNOSTIC MONITOR DIAGNOSTIC TROUBLE CODE PRIORITY TABLE

Priority	Code	Component/Fault Description
Highest	—	No Air Bag Indicator — Inoperative Lamp Circuit or No Ignition Voltage for Air Bag Diagnostic Monitor
	—	Continuous Air Bag Indicator — Air Bag Diagnostic Monitor Disconnected or Inoperative
	12	Low Battery Voltage
	13	Air Bag Circuit Shorted to Ground
	14	Primary Crash Sensor Circuit Shorted to Ground
	21	Safing Sensor Not Mounted to Vehicle Properly
	22	Safing Sensor Output Shorted to Battery Voltage
	23	Safing Sensor Circuit Input Feed/Return Circuit Open
	24	Safing Sensor Output Feed/Return Circuit Open
	32	Driver Side Air Bag Module High Resistance or Open
	33	Passenger Side Air Bag Module High Resistance or Open
	34	Driver Side Air Bag Module Low Resistance or Shorted
	35	Passenger Side Air Bag Module Low Resistance or Shorted
	41	Center Cowl Primary Crash Sensor Feed/Return Open
	42	Center radiator Primary Crash Sensor Feed/Return Open
	44	Center Cowl Primary Crash Sensor Not Mounted to Vehicle Properly
	45	Center Radiator Primary Crash Sensor Not Mounted to Vehicle Properly
	51	Diagnostic Monitor Internal Thermal Fuse—Fuse Blown Due to Intermittent Short to Ground
	52	Back-up Power Supply—Voltage Boost Fault
	53	Primary Crash Sensor Circuits—Resistance to Ground or Air Bag Diagnostic Monitor Failure
Lowest	—	Rapid Continuous Flashing of Air Bag Indicator (No DTC) All Primary Crash Sensors Disconnected

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Pinpoint Tests

Use Rotunda 88 Digital Multi-Meter 105-00053 or equivalent to obtain voltage and resistance readings for the following Pinpoint Tests.

No Air Bag Indicator—Inoperative Lamp Circuit or No Ignition Voltage to Air Bag Diagnostic Monitor

Normal Operation

The air bag warning indicator is designed to light for 6 ±2 seconds when the ignition switch (11572) is turned to RUN. This initial six seconds of air bag warning indicator illumination (continuous lamp) is considered normal operation and is called "prove out" of the air bag warning indicator.

The air bag diagnostic monitor (14B056) requires power at Pin 1 in order to energize the air bag warning indicator circuit. If the air bag warning indicator circuit is open or if the air bag diagnostic monitor does not have ignition voltage at Pin 1, then the air bag warning indicator will not light.

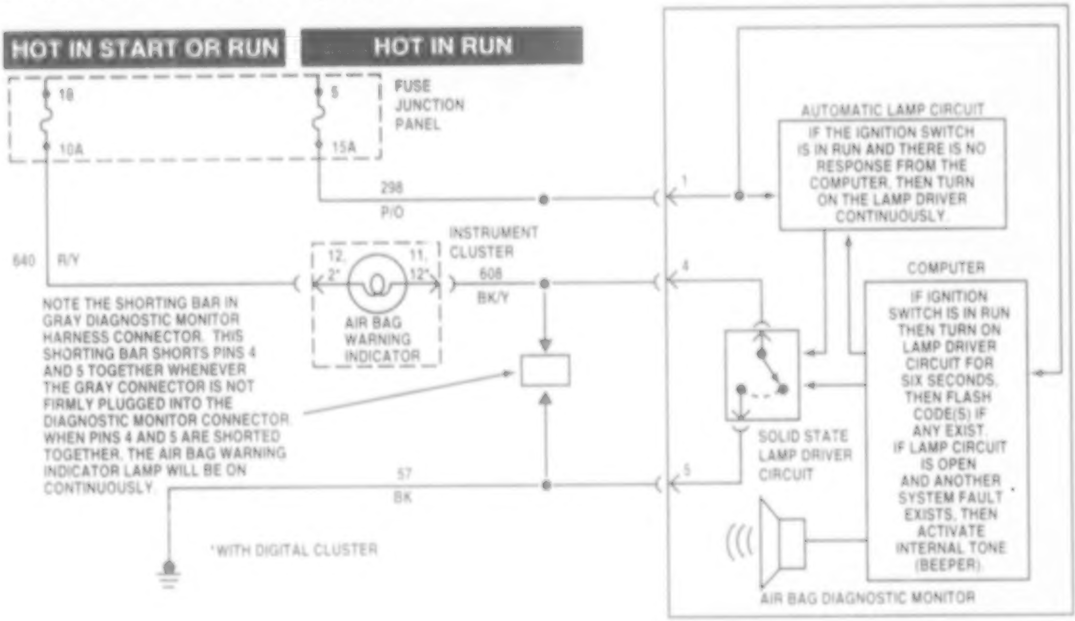
If the computer in the air bag diagnostic monitor detects an open in the air bag warning indicator lamp circuit and, if another system fault exists, then the air bag diagnostic monitor will turn on its internal tone generator (beeper). The beep pattern is five sets of five beeps. The pattern is repeated every 30 minutes while the ignition switch is in RUN. The five beeps do not indicate a code 55 or any other code. The air bag warning indicator lamp circuitry must be serviced before the diagnostic trouble code can be read.

Possible Causes

A No Air Bag Indicator condition can be caused by:

1. **A burned-out bulb or open wiring in the air bag indicator circuit.**
2. **Loss of ignition voltage at Pin 1 of the diagnostic monitor.**

Electrical Schematic—No Air Bag Indicator


HOT IN START OR RUN
HOT IN RUN
18
10A
5
15A
FUSE
JUNCTION
PANEL
298
P/O
640
R/Y
INSTRUMENT
CLUSTER
12,
2*
11,
12*
608
BK/Y
AIR BAG
WARNING
INDICATOR
NOTE THE SHORTING BAR IN GRAY DIAGNOSTIC MONITOR HARNESS CONNECTOR. THIS SHORTING BAR SHORTS PINS 4 AND 5 TOGETHER WHENEVER THE GRAY CONNECTOR IS NOT FIRMLY PLUGGED INTO THE DIAGNOSTIC MONITOR CONNECTOR. WHEN PINS 4 AND 5 ARE SHORTED TOGETHER, THE AIR BAG WARNING INDICATOR LAMP WILL BE ON CONTINUOUSLY.
57
BK
*WITH DIGITAL CLUSTER
1
4
5
AUTOMATIC LAMP CIRCUIT
IF THE IGNITION SWITCH IS IN RUN AND THERE IS NO RESPONSE FROM THE COMPUTER, THEN TURN ON THE LAMP DRIVER CONTINUOUSLY.
COMPUTER
IF IGNITION SWITCH IS IN RUN THEN TURN ON LAMP DRIVER CIRCUIT FOR SIX SECONDS, THEN FLASH CODE(S) IF ANY EXIST. IF LAMP CIRCUIT IS OPEN AND ANOTHER SYSTEM FAULT EXISTS, THEN ACTIVATE INTERNAL TONE (BEEPER).
SOLID STATE
LAMP DRIVER
CIRCUIT
AIR BAG DIAGNOSTIC MONITOR

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PINPOINT TEST A: NO AIR BAG INDICATOR

TEST STEP		RESULT ▶	ACTION TO TAKE
A1	CHECK FOR IGNITION VOLTAGE • Deactivate system. • Disconnect air bag diagnostic monitor. • Turn Ignition Switch to RUN. • Measure voltage between Pins 1 Circuit 298 (P/O)(+) and 3 Circuit 57 (BK) (-). • **Is voltage measured equal to battery voltage?**	Yes ▶	Go to **A2.**
		No ▶	SERVICE open circuit in "HOT IN RUN" Circuit 298 (P/O) from fuse panel. CHECK Fuse 5. CHECK for proper ground on Pin 3 of air bag diagnostic monitor connector. RECONNECT system. VERIFY system. REACTIVATE system.
A2	CHECK FOR OPEN AIR BAG WARNING INDICATOR LAMP CIRCUIT • Leave air bag diagnostic monitor disconnected and turn Ignition Switch to RUN. • **Is air bag warning indicator on?**	Yes ▶	REPLACE air bag diagnostic monitor. RECONNECT system. VERIFY system. REACTIVATE system.
		No ▶	LOCATE and SERVICE open circuit in air bag warning indicator circuitry. CHECK for burned-out bulb, blown Fuse 18, open connections, pushed-out pins, etc. RECONNECT system. VERIFY system. REACTIVATE system.

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CONTINUOUS AIR BAG INDICATOR—AIR BAG DIAGNOSTIC MONITOR DISCONNECTED OR INOPERATIVE

Normal Operation

The Air Bag Warning Indicator is designed to illuminate for 6 ± 2 seconds when the Ignition Switch is turned to RUN. The initial six seconds of Air Bag Warning Indicator illumination (continuous lamp) is considered normal operation and is called "prove out" of the Air Bag Warning Indicator. If the air bag diagnostic monitor detects any faults in the air bag system following prove out, it will flash the Air Bag Warning Indicator a series of times to indicate the diagnostic trouble code that has been detected. If the Air Bag Warning Indicator comes on when the Ignition Switch is turned to RUN and stays on for more than eight seconds continuously, then a fault exists in the Air Bag Warning Indicator circuit.

The air bag diagnostic monitor incorporates a solid-state circuit that shorts the air bag warning indicator line (Circuit 608 BK/Y) to ground to turn the Air Bag Warning Indicator on. When the gray air bag diagnostic monitor harness connector is unplugged from the air bag diagnostic monitor, a shorting bar within the harness connector connects Pins 4 (air bag warning indicator) and 5 (ground) together. The shorting bar will turn the Air Bag Warning Indicator on whenever the gray air bag diagnostic monitor harness connector is disconnected. Because the shorting bar makes a continuous connection between Pins 4 and 5 when the connector is disconnected, the Air Bag Warning Indicator will not flash—Instead, it will glow continuously.

When the Ignition Switch is turned to RUN, the air bag diagnostic monitor "wakes up" and, after approximately six seconds, turns the Air Bag Warning Indicator off. If the air bag diagnostic monitor fails to "wake up," the lamp driver circuit will automatically turn the Air Bag Warning Indicator on continuously, indicating a concern in the air bag diagnostic monitor or at the gray air bag diagnostic monitor connector.

Possible Causes

Continuous illumination of the Air Bag Warning Indicator can be caused by:

1. A disconnected or poorly connected air bag diagnostic monitor may not push the shorting bar between Pins 4 and 5 into its fully retracted position. This shorts the Air Bag Warning Indicator line to ground and causes the Air Bag Warning Indicator to glow continuously.
2. Shorted Air Bag Warning Indicator wiring.
3. A damaged air bag diagnostic monitor.

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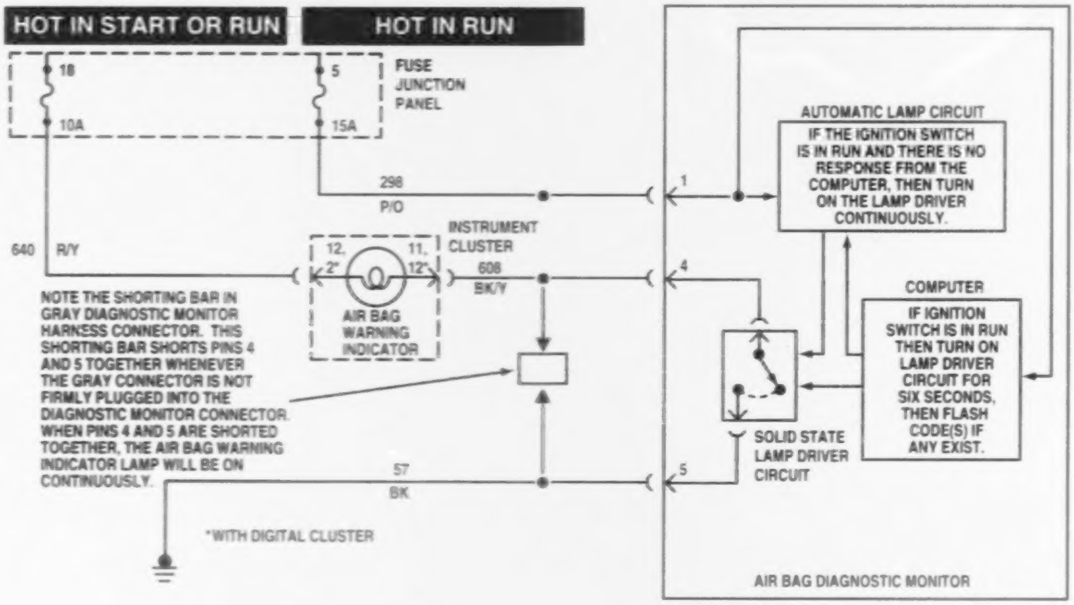
Assignment Sheet 5

1. **A disconnected or poorly connected air bag diagnositc monitor** may not push the shorting bar between Pins 4 and 5 into its fully retracted position. This shorts the Air Bag Warning Indicator line to ground and causes the Air Bag Warning Indicator to glow continuously.
2. **Shorted Air Bag Warning Indicator wiring.**
3. **A damaged air bag diagnostic monitor.**

Electrical Schematic—Continuous Air Bag Indicator


HOT IN START OR RUN
HOT IN RUN
18
10A
5
15A
FUSE JUNCTION PANEL
298
P/O
640
R/Y
12, 2*
11, 12*
INSTRUMENT CLUSTER
608
BK/Y
AIR BAG WARNING INDICATOR
57
BK
1
4
5
AUTOMATIC LAMP CIRCUIT
IF THE IGNITION SWITCH IS IN RUN AND THERE IS NO RESPONSE FROM THE COMPUTER, THEN TURN ON THE LAMP DRIVER CONTINUOUSLY.
COMPUTER
IF IGNITION SWITCH IS IN RUN THEN TURN ON LAMP DRIVER CIRCUIT FOR SIX SECONDS, THEN FLASH CODE(S) IF ANY EXIST.
SOLID STATE LAMP DRIVER CIRCUIT
AIR BAG DIAGNOSTIC MONITOR

NOTE THE SHORTING BAR IN GRAY DIAGNOSTIC MONITOR HARNESS CONNECTOR. THIS SHORTING BAR SHORTS PINS 4 AND 5 TOGETHER WHENEVER THE GRAY CONNECTOR IS NOT FIRMLY PLUGGED INTO THE DIAGNOSTIC MONITOR CONNECTOR. WHEN PINS 4 AND 5 ARE SHORTED TOGETHER, THE AIR BAG WARNING INDICATOR LAMP WILL BE ON CONTINUOUSLY.

*WITH DIGITAL CLUSTER

1337

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PINPOINT TEST B: CONTINUOUS AIR BAG INDICATOR

TEST STEP		RESULT ▶	ACTION TO TAKE
B1	CHECK IF AIR BAG DIAGNOSTIC MONITOR IS		
	• Deactivate system. • Inspect connectors on air bag diagnostic monitor. • **Are connectors fully pushed together?**	Yes ▶	Go to **B2.**
		No ▶	Firmly MATE connectors to air bag diagnostic monitor. RECONNECT system. VERIFY system. REACTIVATE system.
B2	CHECK AIR BAG WARNING INDICATOR LAMP CIRCUITRY		
	• Disconnect air bag diagnostic monitor. • Remove plastic locking wedge from gray air bag diagnostic monitor harness connector. • Turn ignition switch to RUN. • **Is air bag warning Indicator on?**	Yes ▶	SERVICE short to ground in Circuit 608 (BK/Y) between air bag warning indicator lamp and air bag diagnostic monitor. RECONNECT system. VERIFY system. REACTIVATE system.
		No ▶	Go to **B3.**
B3	INSPECT SHORTING BAR		
	• Inspect shorting bars on plastic locking wedge for proper operation. • **Is shorting bar in good working order?**	Yes ▶	REPLACE air bag diagnostic monitor. RECONNECT system. VERIFY system. REACTIVATE system.
		No ▶	REPLACE plastic locking wedge. Make sure replacement has shorting bars on the locking wedge. RECONNECT system. VERIFY system. REACTIVATE system.

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Diagnostic Trouble Code 12—Low Battery Voltage

Normal Operation

The air bag diagnostic monitor measures the voltage at Pin 13 of the air bag diagnostic monitor connector. Voltage at Pin 13 should be equal to battery voltage. If the voltage measured at Pin 13 drops to less than 9 volts, the diagnostic monitor will flash out code 12.

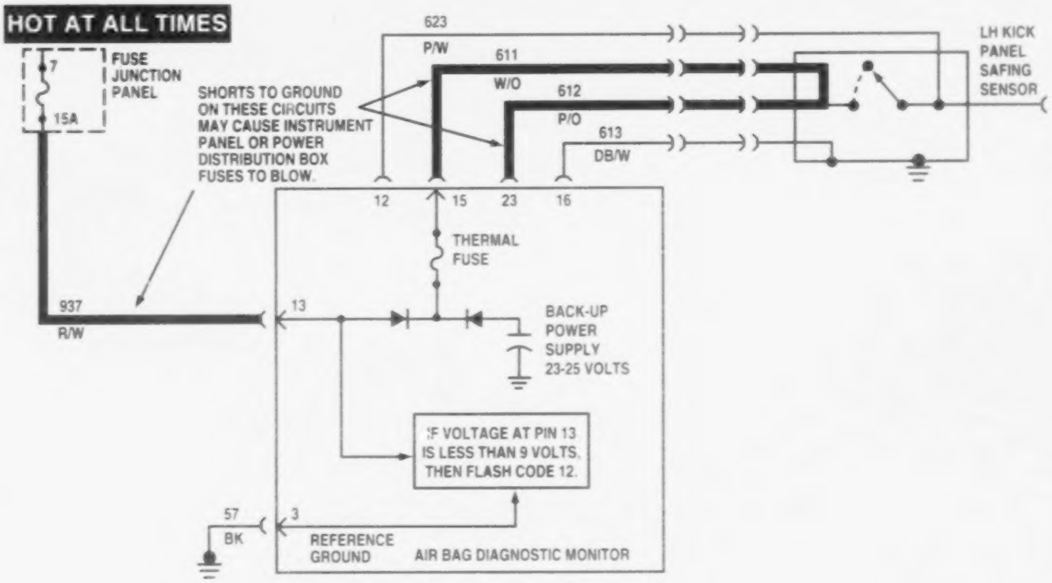
Possible Causes

Low battery voltage at diagnostic monitor Pin 13 can be caused by:

NOTE: If Fuse 7 is blown, make sure to diagnose the system for Possible Causes 1, 2 and 3.

1. **A short to ground in Circuit 611 (W/O) or 612 (P/O)** may result in a blown Fuse 7.
2. **An internal short to ground within the LH kick panel safing rear air bag sensor and bracket (14B007)** may result in a blown Fuse 7.
3. **A short to ground on the battery feed circuit 937 (R/W)** between the fuse and Pin 13 of the air bag diagnostic monitor may result in a blown Fuse 7.
4. **A concern in the charging system** causing battery voltage to drop below 9 volts.

Electrical Schematic—Diagnostic Trouble Code 12


HOT AT ALL TIMES
7
15A
FUSE JUNCTION PANEL
SHORTS TO GROUND ON THESE CIRCUITS MAY CAUSE INSTRUMENT PANEL OR POWER DISTRIBUTION BOX FUSES TO BLOW.
623
P/W
611
W/O
612
P/O
613
DB/W
LH KICK PANEL SAFING SENSOR
12
15
23
16
THERMAL FUSE
937
R/W
13
BACK-UP POWER SUPPLY 23-25 VOLTS
IF VOLTAGE AT PIN 13 IS LESS THAN 9 VOLTS, THEN FLASH CODE 12.
57
BK
3
REFERENCE GROUND
AIR BAG DIAGNOSTIC MONITOR

1359

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RAPID CONTINUOUS FLASHING OF AIR BAG INDICATOR (No DTC) ALL PRIMARY CRASH SENSORS DISCONNECTED

Normal Operation

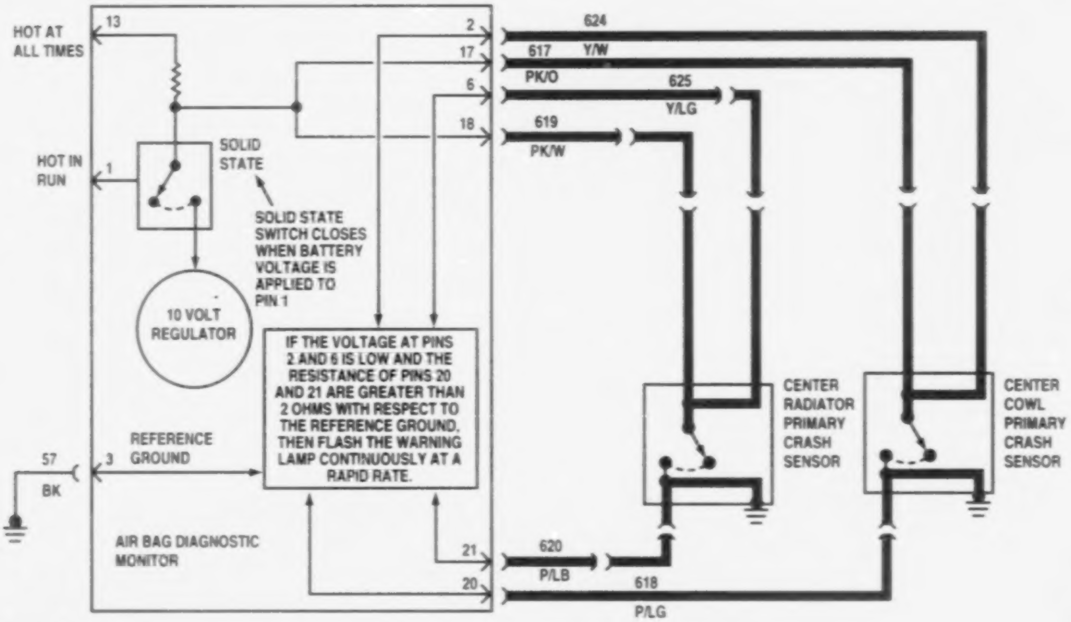
Each primary crash sensor has three wires. Two of the wires are used for air bag deployment and monitoring the sensor's connection to the air bag diagnostic monitor (refer to Diagnostic Trouble Codes 41 and 42 diagnosis as outlined). The other wire is used for monitoring the mounting (ground) of the primary crash sensor to sheet metal (refer to Diagnostic Trouble Codes 44 and 45 diagnosis as outlined). If diagnosis reveals that BOTH primary crash sensors are not properly grounded, the air bag diagnostic monitor will flash the air bag indicator continuously at a fast rate.

Possible Causes

WARNING: THE ELECTRICAL CIRCUIT NECESSARY FOR SYSTEM DEPLOYMENT IS POWERED DIRECTLY FROM THE BATTERY. TO AVOID ACCIDENTAL DEPLOYMENT AND POSSIBLE PERSONAL INJURY, THE NEGATIVE MUST BE DISCONNECTED PRIOR TO SERVICING OR REPLACING ANY SYSTEM COMPONENTS.

1. All primary crash sensors disconnected from wiring harness or main wiring harness not connected with engine compartment wiring harness.

Electrical Schematic—Rapid Continuous Flashing of Air Bag Indicator


HOT AT ALL TIMES
13
HOT IN RUN
1
SOLID STATE
SOLID STATE SWITCH CLOSES WHEN BATTERY VOLTAGE IS APPLIED TO PIN 1
10 VOLT REGULATOR
IF THE VOLTAGE AT PINS 2 AND 6 IS LOW AND THE RESISTANCE OF PINS 20 AND 21 ARE GREATER THAN 2 OHMS WITH RESPECT TO THE REFERENCE GROUND, THEN FLASH THE WARNING LAMP CONTINUOUSLY AT A RAPID RATE.
REFERENCE GROUND
57
3
BK
AIR BAG DIAGNOSTIC MONITOR
2
17
6
18
21
20
624
617
Y/W
PK/O
625
Y/LG
619
PK/W
620
P/LB
618
P/LG
CENTER RADIATOR PRIMARY CRASH SENSOR
CENTER COWL PRIMARY CRASH SENSOR

Pinpoint Tests

Refer to Pinpoint Tests for Diagnosis Trouble Codes 41, 42, 44, and 45.

Diagnostic Trouble Code Clearing

Refer to Deactivation Procedure steps 1, 2, and 3.

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Assignment Sheet 5

REMOVAL AND INSTALLATION

Sensor and Bracket, Center

Removal

NOTE: To service stripped center radiator primary crash sensor retaining screw at center radiator primary crash front air bag sensor and bracket (14B005), use screw (Part No. N802455-S190). Tighten to 13-17 N•m (10-12 lb-ft).

1. Disconnect negative battery cable.
2. Wait one minute for back-up power supply energy to be depleted.
3. Remove radiator upper sight shield (8C291).
4. Disconnect center radiator primary crash sensor electrical connector.
5. Remove four screws retaining center radiator primary crash front air bag sensor and bracket to radiator support (16138). Remove center radiator primary crash front air bag sensor and bracket from vehicle.

Installation

1. Position center radiator primary crash front air bag sensor and bracket with arrow on top pointing toward front of vehicle and secure to radiator support with four screws. Tighten screws to 6.8-9.2 N•m (60-81 lb-in).
2. Connect center radiator primary crash sensor wire lead connector to wiring assembly connector.
3. Install radiator upper sight shield.
4. Reconnect negative battery cable.

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____ 1. While servicing the air bag system, Technician A says that a code 53 is a high priority code. Technician B says that a 53 is a low priority code. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 2. A client complains that the air bag indicator light does not illuminate. Technician A says that a burned out bulb could be the problem. Technician B says that loss of voltage at pin 1 of the diagnostic monitor could be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 3. A vehicle's air bag indicator lamp continuously illuminates. Technician A says that a shorted air bag warning indicator wiring could be the cause. Technician B says a damaged air bag diagnostic monitor could be the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 4. A diagnostic code 12 is found in the air bag system. Technician A says that this is normal operation. Technician B says that high voltage at pin 13 is the cause. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

____ 5. An air bag indicator continually flashes. To test the system, Technician A says to disconnect the negative battery cable before servicing or replacing any system components. Technician B says the air bag system could accidentally deploy and cause personal injury. Who is correct?

a. Technician A
b. Technician B
c. both Technician A and B
d. neither Technician A nor B

Objective 19

Job Sheet 1—Inspect, Test, Repair, and Replace the Parts of a Power Window

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Power window motors are relatively expensive. Therefore, many facilities may choose to service rather than replace them. Your job may involve refurbishing contacts and similar components. (Many power window motors use replaceable plastic gears that sometimes crack, strip, or wear.) You can follow standard repair procedures for wiring and connectors. Some regulators are adjustable.

Safety Concerns

> Warning: If the vehicle is equipped with side airbags, consult the service manual for proper procedures prior to troubleshooting or repairing window components.

a. Observe all rules for electrical safety.

b. Be aware of mechanical hazards:

- The springs used with some power window regulators can slip from their attaching point or break, it can fly through the air with enough force to cause injury.
- The operating area of the window and regulators can pinch or smash fingers and other body parts that get in the path of moving parts.

Service Guidelines

a. Become familiar with the circuit diagram. Not all power window systems operate in the same way. Using this information, determine the probable cause of the problem from the indications:

- If one window does not operate but the others do, then the problem may be the switch, the motor, or the wiring associated with that window.
- If all windows are affected, then the problem may be a bad fuse or a tripped circuit breaker.
- If the windows will go up but not down, then the problem may be a defective relay.

b. **Verify the customer's complaint**; confirm that the system is not operating as it is designed to operate.

Examples: A customer may report that only the driver's window has one-touch operation. In most vehicles with this option, it is only available on the driver's side. Customers who do not know this may report that the windows are not operating properly.

c. Consider the location of components when deciding where to test a circuit if either the switch or motor is suspect. Most troubleshooting procedures apply this principle. While you can generally reach switches without much difficulty, motors and regulators are often difficult to access because they are "buried" within the door.

Example: If one motor does not work while the other does, the procedure may direct you to check the supply and ground sides of the switch first, followed by the switch, and then the motor if the other components are good.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

1345

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

1346

1347

Objective 20

Job Sheet 2—Inspect, Test, Repair, and Replace the Parts of a Heated, Lighted, and Electrically Operated Mirror

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Design and Operation

Electrically operated mirrors use a variety of control designs and may use cables or rods to move the mirror face. Each exterior mirror may have separate controls or a single switch to control either mirror. You must thoroughly understand the electrical circuitry in order to diagnose and service these mirrors.

Mirrors equipped with defoggers are likely to have separate operating circuits for the heating elements and the adjustment mechanisms. Make sure you understand the differences in these two circuits and the wiring and components associated with each before servicing the unit.

Service Guidelines

- Be patient when looking for access to internal components. Manufacturers conceal fasteners, so the means for gaining access to the internal components of the mirror, including the motors, may not be obvious.
- Follow the manufacturer's instructions for removing or opening the mirror. Some vehicles actually require you to break the mirror face to gain access to the motors. If so, use care not to scatter the glass and remove all of the glass to prevent injury or damage to moving parts.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 2

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 21

Job Sheet 3—Inspect, Test, Repair, and Replace the Parts of an Electric Door Lock

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Operation

Operation of the internal lock switches or key cylinders at different doors in different ways can produce different results. For example, on one vehicle, it may be possible to lock or unlock all doors by quickly making contact twice when turning the key cylinder or to open only that door with a single contact. On a second vehicle, the key cylinder may operate only the lock on that door. For one model, either of the front door lock switches may be capable of operating all of the locks, while on another model only the driver's door has that capability.

Most vehicles now use motors to operate door locks because solenoids drain more power. However, many systems in use have solenoids. Solenoids work well for door locks because movement of only a short distance is required to engage or disengage the locking mechanism. The solenoid plunger engages the lock in one direction, while reversing current polarity causes the plunger to move in the other direction to unlock the door. Some solenoids are adjustable. Power door lock circuits are subject to standard repair procedures for wiring and connectors. You must replace other parts if they are defective.

Service Guidelines

- Check the circuit diagram and service manual to determine system operation, not only to support testing and servicing but to assist with verifying the customer's complaint.
- Note that the number of doors affected can tell you a lot about the probable cause of defective door lock operation.

  Note: A failure at a single door or in either the lock or unlock function may indicate a defective component in the circuit for that door. A failure in the operation of all of the doors may indicate a problem with a power source, master switch, circuit protection, or relay module.

- Verify that the problem may involve a component inside the door before removing the door panel.
- Note that a vehicle may have automatic door locks that actuate whenever the transmission is shifted from PARK or once the vehicle reaches a given speed. Components of the automatic system may affect the operation of power locks.
- Ensure that the battery is fully charged. Power locks work directly off the battery and are often operated without the vehicle running.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Objective 22

Job Sheet 4—Inspect, Test, Repair, and Replace the Parts of Anti-Theft Systems

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

Introduction

"Pass-key" systems

More recent anti-theft systems involve the ignition switch and the key. These systems work even when other anti-theft systems are not armed. The key used in the ignition switch must match a code stored in memory in one of the vehicle control modules. The three most common matching characteristics currently in use include the following:

- **Resistance matching**—When the key is turned in the ignition switch lock cylinder, its resistance value through a resistor pellet is measured and compared to a value stored in a decoder module; if the values match, the starter relay closes and the electronic control module is signaled to begin fuel delivery.

- **Magnetic identity matching**—When the key is inserted in the ignition switch lock cylinder, its magnetic properties are measured by a Hall-effect sensor; if the key does not have the correct magnetic characteristics, the starter circuit will not be closed even if the lock cylinder turns.

- **Radio code matching**—When the key is turned in the ignition switch lock cylinder, a transmitter in the key sends a coded signal to the key circuit as the starter is engaged; if the codes do not match, the ignition system will be disabled when the switch returns to the ON position.

Service Guidelines

Some theft-deterrent systems are purely mechanical, while others are primarily electronic. You must analyze a system before servicing it, not only due to the variety of systems but also because vehicle manufacturers offer several choices in anti-theft systems.

Be aware of the interaction between the security system and other electrical circuits, such as the horn, headlights, ignition switch circuit, etc. For example, an apparent headlight problem may actually be a security circuit defect; the horn chirp that normally signals arming of the alarm system may be a horn circuit fault rather than a security system problem.

You can perform most of the work using the service manual. However, many vehicles have aftermarket security systems requiring the use of other documentation. While your service facility may choose not to service such systems, you must know how those systems may affect other circuits that you will be servicing.

There are two general types of security system malfunctions:

- An anti-theft system may fail to operate when it should. It may not arm or disarm as required or may not activate in a security situation.
- A system may also operate when it should not. The alarm may sound when there is no intrusion or the vehicle may become inoperable when the system should be disarmed.

The two most common causes of failure are a malfunction of a sensor or of the system controller. The components are not serviceable. You must replace them if they are defective.

Because the anti-theft system is tied to other circuits, there may be interdependent failures. For example, if the horn does not sound when the system is activated or does not sound when the alarm is activated, the problem may be in the anti-theft module, the horn circuit, or the interface between the two. Similarly, if the horn does not sound when the horn button is pushed, a problem with the horn circuit or a short or other defect in the anti-theft circuit may be preventing power from reaching the horn.

Some systems may not function until 20 engine cranks. Check to determine whether a new powertrain control module has been installed recently.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 23

Job Sheet 5—Inspect, Test, Repair, and Replace the Parts of a Sound System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Other than wires and connectors, most sound system components are not repaired at most heavy duty truck repair facilities. Audio specialty companies perform much of the repair of radios, cassette players, and compact disc players. Speakers are generally replaced, although some audio shops will repair speakers.

Service Guidelines

- Evaluate the impact of changes to audio systems. Service procedures generally address step-by-step repair processes. However, they cannot anticipate every possible situation, such as a customer who has requested more powerful speakers or replacement of an AM radio with an AM/FM tuner with cassette and CD players.
- Identify the effects of defective components.
- Analyze the interrelationship of audio and other systems.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Job Sheet 5

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

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Job Sheet 5

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Objective 24

Job Sheet 6—Remove and Reinstall Audio System Components (Unit)

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	____
• Safety procedures are followed	____
• Service manual is used properly	____
• Procedures followed accurately	____
• Job ticket is filled out properly	____
• Cleanup is adequate	____

Basic Skills

Reading Science Critical Thinking Employability

Introduction

You must often remove and reinstall audio components as part of a repair procedure or when a customer wants to upgrade the audio system, such as by adding a CD player or installing higher quality speakers. Occasionally, you may have to remove audio system components to perform other service procedures. For example, you may have to remove the radio to gain access to components behind the instrument panel, such as wiring harnesses, keyless entry modules, air bag components, etc. You may also have to remove speakers to reach other components, including power lock and power window circuits.

Service Guidelines

a. Make sure that you can (1) do what is required to remove or secure the component mechanically and (2) connect or disconnect it electrically.

  - The need for an attractive and secure installation can complicate the job of component removal and installation. Door and dashboard trim is generally designed to hide fasteners and to provide an almost seamless installation. This makes it difficult to determine how the panels fit together. You must be careful to follow the manufacturer's instructions to avoid damaging trim components.

  - Generally, removal and installation of audio system components is done with the battery disconnected. You may also have to isolate other systems, such as remote controls, before removing or installing the sound system. Once you have installed or reinstalled the system, you may have to set the clock, program radio stations, or reinitialize other electronic systems after reconnecting the battery.

b. You may need audio system service manuals to complete the job, especially when upgrading the system. Be especially careful to ensure that the electrical demands of the system are met. For example, an upgraded sound system may require additional circuit protection, such as an in-line fuse or fusible link. Speakers may have a specific polarity or require special grounds, such as a separate wire floating ground. Make sure that you thoroughly understand the operation and characteristics of the system before performing the required service.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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____

Job Sheet 6

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 25

Job Sheet 7—Inspect, Test, Repair, and Replace the Parts of an Airbag System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

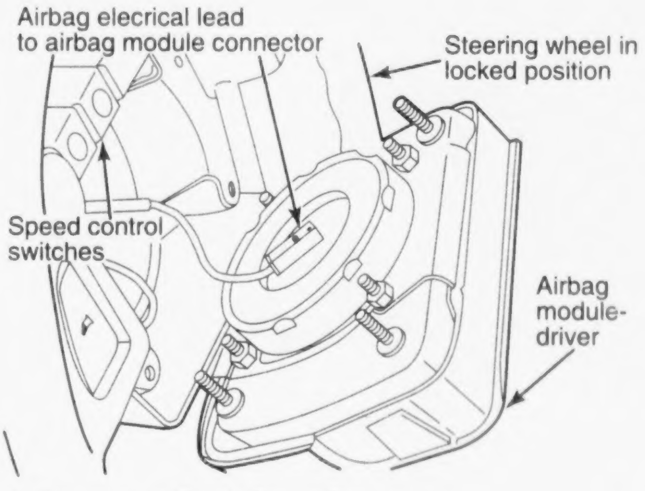
Reading Science Critical Thinking Employability

Introduction

Component Locations

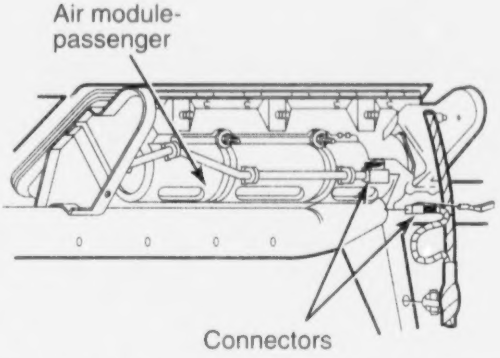
Airbag modules may provide front-impact protection in the steering wheel. Figure 1 shows a driver's airbag module removed from the steering wheel. Figure 2 shows the reverse view of a passenger airbag module installed in the right side of the instrument panel.

Figure 1


Airbag elecrical lead to airbag module connector
Steering wheel in locked position
Speed control switches
Airbag module-driver

Used with permission of DaimlerChrysler Corp.

Figure 2



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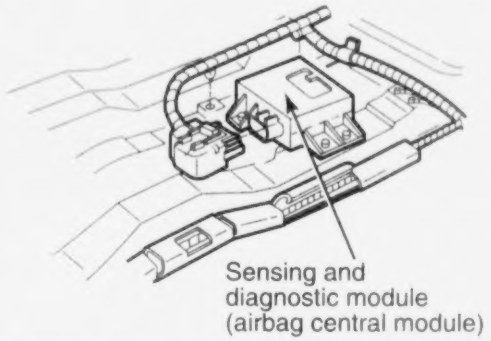
Because airbags are not routinely used, you have fewer opportunities to discover malfunctions. However, most airbag systems include self-diagnostic systems. Generally, each time the engine is started, the airbag system conducts a self-test and reports malfunction codes to the sensing and diagnostic module. You can access this module with test equipment. Figure 3 shows a sensing and diagnostic module located on the right side floor.

Figure 3



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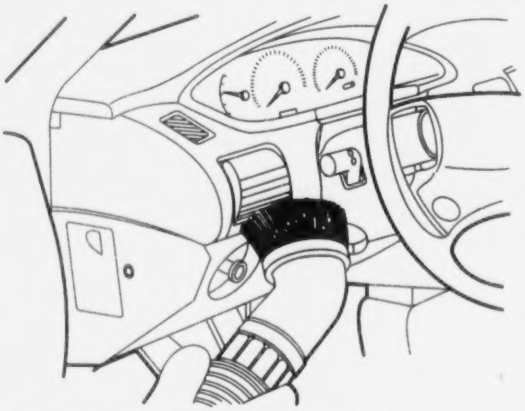
Service Guidelines

a. The most common service requirement for airbag systems is the replacement of systems that have deployed. Most components cannot be repaired and must be replaced; many systems require that all components be replaced once a system deploys.

> Warning: Airbags inflate with significant force. Use care when servicing airbag systems and working around them. Dangers are associated with various stages of installation.

b. When servicing deployed airbag systems, wear protective gloves, eye protection, and respirators. You may also have to run the air conditioning system and use a vacuum to control the powder from a deployed airbag (Figure 4)

Figure 4



Used with permission of DaimlerChrysler Corp.

c. Handle and service live (undeployed) airbag systems with extreme caution:

- Follow the manufacturer's procedures for handling, servicing and testing airbag systems and related circuits.
- Wear safety glasses when servicing an airbag system or handling airbag modules.
- De-energize the system before servicing live airbag modules. You may also have to de-energize the system when servicing other systems, such as those housed in the steering wheel or steering column.
  - — Disconnect the battery, then wait at least 10 minutes before servicing the airbag system.

    Note: Airbag systems include a diagnostic and energy reserve module that allows deployment of the airbag even after the loss of battery power. The reserve time varies with different systems. Check the service manual for exact time specifications.
  - — Do not use powered test equipment or test lights to probe airbag circuits except as specifically described by the service procedures.
- Be careful not to drop, strike or jar sensor modules connected to live airbag systems.

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- Carry live airbag modules with the bag opening (trim cover on driver's airbag module, plastic cover on passenger's module) pointing away from your body.
- Do not carry airbag modules by the wires or connectors.
- When (1) placing an airbag module on a bench or other surface, or (2) handling an airbag module attached to a steering column, make sure that the airbag module always faces away from the surface:
  - — Place an uninstalled live airbag module with its trim or plastic cover facing upward from the bench or other surface and away from loose objects.
  - — Place a live airbag module attached to a steering column so the airbag module does not face the floor.

    Note: This will reduce the amount of movement by the component (and the potential for injury) in the case of accidental deployment.
- Follow the disarming procedure exactly. Some systems remain armed for a period of time after power is removed.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

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PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________________

Date Out ______________________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________________

Technician ______________________

Supervisor ______________________

Objective 26

Job Sheet 8—Inspect, Test, Repair, and Replace the Parts of a Cigar Lighter/Auxiliary Power Outlet

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Procedures followed accurately	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Science Critical Thinking Employability

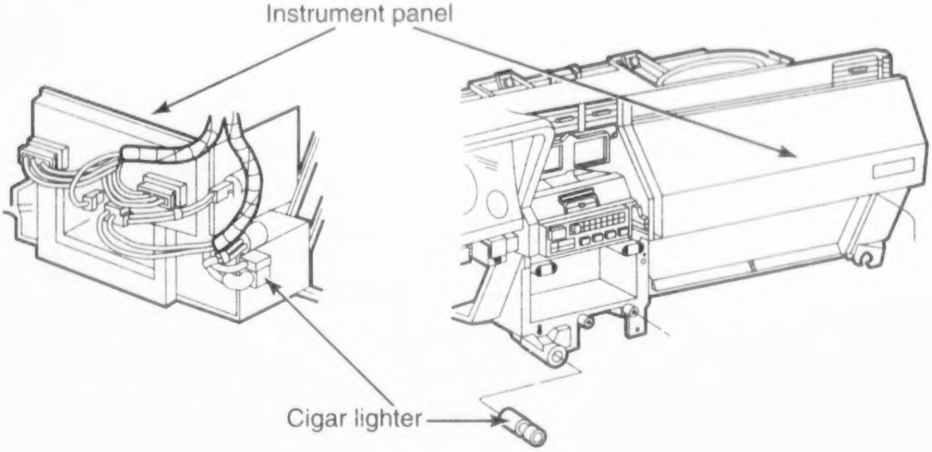
Introduction

Function and Location

A cigar lighter is designed to produce heat. However, today's vehicles often provide circuits that go beyond that basic function. Accessories such as radar detectors, electric shavers, cellular phones, laptop computers, and other devices have been developed with adapters. These adapters plug into the cigar lighter receptacle to power those accessories off the battery. As a result, many vehicles now offer power receptacles instead of cigar lighters or in addition to cigar lighters. Power receptacles act as electrical outlets.

Cigar lighters and power receptacles are wired in much the same way. Cigar lighters are basically resistive switches. Pushing the lighter into its socket closes the circuit. Current flows through the heating element, building up heat due to the resistance of the conductor. As the element heats, it expands, causing the spring-loaded shell to break contact with the power terminal. The lighter can then be used. When used as a power outlet, the lighter socket simply provides access to a battery circuit. The power terminal is always powered or powered when the ignition switch is in the ON or ACCESSORY position, and the shell is grounded to the chassis. Adapters are available that plug into the lighter socket to complete the circuit without a resistive heating element. The adapter may be on the end of a power cord for equipment designed primarily for use in a vehicle. It may also be a separate component that plugs into the lighter socket and accepts various types of DC power cords. The cigar lighter is often located in or near an ashtray near the center of the instrument panel (Figure 1). Some luxury trucks offer an additional cigar lighter for the rear sleeper compartment.

Figure 1



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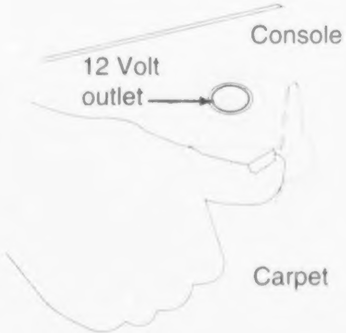
Power receptacles operate in the same way as the cigar lighter when used as a power outlet. (Some power outlets even accept cigar lighters.) However, most are intended for use as a power source connection for various types of electrical equipment. Many vehicles, such as trucks with sleepers, may have more than one power receptacle. When more than one power outlet is provided, they may have different functions and may operate differently. For example, some may accept lighters while others do not. Some may operate only when the switch is ON or in ACCESSORY. An outlet that is primarily intended to power a cooler or small refrigerator may be wired directly to the battery circuit. Power receptacles are often located near the center of the dash or in a console between the front seats (Figure 2). Other power outlets may be located in the rear section of the vehicle.

Figure 2



Safety Concerns

Cigar lighters become hot enough to burn flesh and ignite fires. Both cigar elements and power receptacles may present exposed electrical circuits. While neither component produces a current that is likely to cause *direct* injury, an unexpected electrical shock may surprise you and cause injury *indirectly*.

Service Guidelines

a. Because cigar lighter and power receptacle components are not serviceable and typically exhibit defects as a complete failure, service manuals may offer little information about them. Procedures may cover little more than component removal or installation. Therefore, you may have to rely on circuit diagrams for much of the information needed to troubleshoot and repair these components.

b. Use routine repair procedures for shorts and opens. Replace failed devices.

c. Most failures of cigar lighters or power receptacles will be in the conductors, connectors, and circuit protection devices. The circuit is likely to be open or shorted if the lighter or outlet is not operational. A lighter may malfunction because the heating element or the spring mechanism have deteriorated. In some cases, enough corrosion may build up in the lighter or receptacle socket to prevent good contact. The components are not generally serviceable and you must replace them.

d. Customers may not understand normal system operation. For example, a customer may make a habit of using a cellular phone or laptop computer without the engine running and with the ignition switch ON. The customer may not realize that other equipment, such as the vent fan and instrument gauges, are also operating. This may cause a drain on the battery. When the vehicle does not start, the customer may complain of a battery or alternator problem. Testing the battery and the alternator will not reveal any defects. Instead, good customer interviewing would identify the customer's own usage habits as the source of the problem.

e. Objects in the ashtray may actuate the lighter when the ashtray is closed and hold it in place so that the spring cannot break contact. In some cases, a metal object such as a coin will get into the lighter socket and complete the circuit. Generally, these situations will cause the fuse to blow. The fuse will frequently serve other circuits, such as the courtesy lights, in which the customer will recognize a failure. As a result, the customer's complaint may be unrelated to the actual source of the problem.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Job Sheet 8

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ________________________________

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Job Sheet 8

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________
Address ______________________
Phone # ______________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ______________________
Customer Address ______________________
Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

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Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________
Supervisor ____________

Objective 27

Job Sheet 9—Inspect, Test, Repair, and Replace the Parts of a Clock

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	
• Safety procedures are followed	
• Service manual is used properly	
• Procedures followed accurately	
• Job ticket is filled out properly	
• Cleanup is adequate	

Basic Skills

Reading Science Critical Thinking Employability

Introduction

Operation

In normal operation, the clock simply displays the time when the engine is running. However, clocks must also allow the driver to set the time. They must also be powered when the engine is off to maintain the correct time. Most clocks have a lighted display. Many allow the driver to check the time with the engine off by pressing a button, such as a radio selector knob. Some clocks are included in other circuits, such as travel information centers, that provide additional computerized data such as average speed, estimated time of arrival, and similar functions. In this case, a defect in the clock circuit may include failing to display the time, displaying an incorrect time, or failing to perform a related function.

Service Guidelines

a. Clock circuits may be a separate circuit or part of the radio unit. Most are digital electronic units and are not typically serviceable. The clocks in some audio units can be separately replaced at a facility that repairs audio components.

b. To gain access to the clock, you may have to remove trim pieces that are installed with hidden fasteners or interlocking parts. Some clocks are fastened to the back of the instrument panel. You may have to remove much of the panel to gain access to the clock.

Job Sheet 9

c Service manuals may yield only circuit diagrams and simple instructions for removing and installing the clock. Clocks that are integrated into radio units may have no separate procedures. You must remove and install them according to the instructions for the *sound system*. You must also exercise care not to damage other circuits that may be near the clock circuit and its wiring harnesses.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket—one is included or use appropriate one provided at your facility
- Wheel chocks
- Safety glasses
- Other equipment and supplies as required by the procedure

Note: Procedures vary with the vehicle. Always check the procedure in the service manual before beginning any service or repair.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Move vehicle into shop, apply the parking brakes, and chock the vehicle wheels. Observe lockout/tagout procedures.

☐ 4. If the vehicle has a manual transmission, place it in "neutral"; if it has an automatic transmission, place it in "park" or "neutral".

Note: Some vehicles with automatic transmissions do not have "park".

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Job Sheet 9

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________